SHEET-METAL WORK

VOLUME II

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SHEET-METAL WORK

A PRACTICAL TREATISE DEALING WITH EVERY PHASE OF THE SHEET-METAL INDUSTRY, INCLUDING MATERIALS, MACHINES, TOOLS, DIE-MAKING AND WELDING METHODS, WITH SPECIAL CHAPTERS ON PLASTICS

BY

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CHAPTER 1

BLANKING PRESSES

BLANKING is a term covering the varied aspects of the punching process which cuts out a shape by means of a punch moving into a die on which the sheet lies. The operation may be confined to that of obtaining a piece for direct use, or one to be drawn or otherwise altered by further processes. A considerable proportion of certain classes of products are blanked and drawn on the same press, and may be further treated at the same stroke, indenting or lettering, etc., being done. Some of the blanking dies are very intricate in form, and only the best type of press is able to use them without causing premature wear or damage to the cutting edges. A good many considerations must be taken into account when making the choice of machine, size of blank for example, the pressure required according to the kind of metal and its thickness, what other operations have to be effected at the same time, and whether automatic feeding is to be applied.

The two main difficulties in regard to blanking consist in avoiding deflection of the frame at the time of penetration (which would cause the die to deviate from its correct path), and reducing the dangerous snap back which occurs when the load is released at the moment that the shearing action is completed. These problems are determined by the type of press employed, its stability, whether tie-rods are fitted, or if it is double-sided. A factor of great importance lies in the amount of shear given to the tools ; this enables the work to be performed at a lower pressure, because of the gradual attack of the cutting edges, and the break-through does not take place suddenly, so that there is no whole release of the pressure, and therefore no spring of the press frame. Even a small amount of shear is beneficial in this latter respect. It is always desirable to use an amply strong press, the more so as fast production on large quantities is essential, hence a double-sided pattern will be chosen in many cases to give high speed with long die life. Or a more powerful size might be selected for continued strenuous duty than that which would be deemed suitable for short runs with similar tools. The requirements naturally vary, depending on the material, whether soft or hard, or annealed metal. Other conditions being equal, a considerable difference may occur in the working of the dies if their clearance is insufficient.

It is a question of primary and secondary shearing. When the proper amount of clearance has been given, the sheet becomes deformed until finally it fractures, and this event should happen simultaneously from the opposed cutting edges of punch and die. With insufficient clearance the metal becomes torn by a secondary shearing action, leaving a ragged edge, and the effect on the press is that it has more work to do, the pressure necessary being spread over a longer period. This secondary shearing action increases as the clearance decreases.

Main Types of Blanking Presses.—The brief résumé given in the previous chapter indicates the principal types of presses employed for various classes of operations. Those specifically for blanking, or blanking and drawing, include many different designs, open-fronted and double-sided, single-die and multiple-die, and with hand or automatic feed. One of the largest machines, having four cranks, and exerting a pressure of 560 tons, cuts out and pierces turbine rotor stampings, 28 inches across the flats, and 16 s.w.g. The weight of the dies is 43 cwt. The C-frame or open-front machine is built in sizes from the little bench models to large geared presses of about 200 tons pressure. The usual disposition of the crankshaft is parallel with the face of the frame, but many, including the punching presses, have it lying at right angles (Fig. 1). The chief functional differences are, whether direct or geared drive is used, and whether the stroke is fixed or variable. Single or double reduction gearing is fitted, according to the heaviness of the duty demanded.

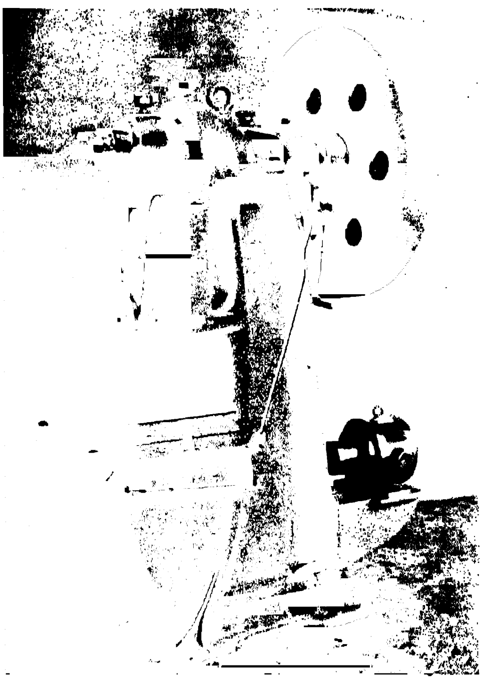


Fig. 1.—End-wheel type of press, which gives a rigid style of frame. (Schuler.)

Automatic Clutch.—The mechanism whereby a press slide is moved may be studied in Fig. 2, this being the style fitted to Taylor & Challen blanking presses. Normally the flywheel rotates freely on the crank-shaft without affecting it, until the starting lever is depressed, by means of a handle or pedal. This lever is connected by a light rod to a double lever A, one end of which acts upon a lug B fixed to the clutch rod C. When the starting lever is depressed the lever A, acting on B, causes the cam plate D to recede from the flywheel, and in doing so allows the key F to shoot by spring pressure into a notch in the hardened-steel bush E, fixed in the flywheel. The shaft and wheel now rotate together, and so impart the

movement to the slide. While the crank is returning on its upward stroke the spring on C pushes the cam D into its former position, and by the time a complete revolution has been made the key F has receded into the shaft again. The crank is thus stopped at the top of the stroke, and the flywheel alone continues to revolve until the starting lever is again moved. The catch G prevents this slide from accidentally dropping, from over-running or other cause. On this catch is fixed the locking arrangement, used when tool-setting; before this is attempted the knurled disk seen on G should be given a half-turn to the right. This will lock the clutch cam in its off position, and so prevent the possibility of the press acting. The tool-setter may now set his dies by turning the crankshaft in its normal direction without troubling to remove the belt from the flywheel. Holes are provided in the brake disk on the end of the shaft to enable it to be turned.

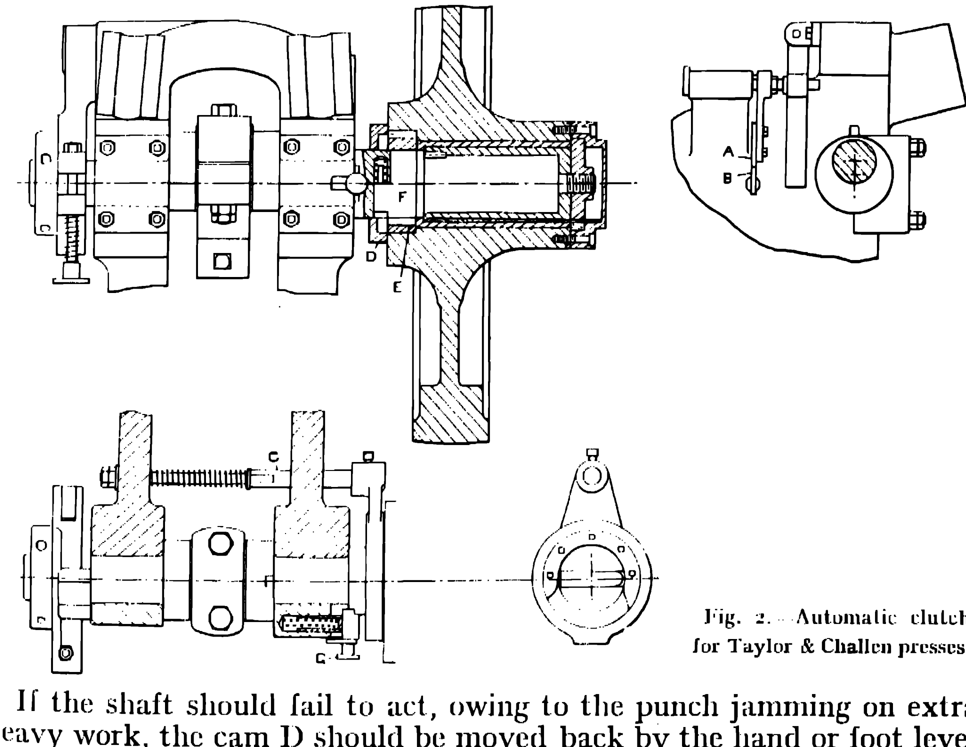


Fig. 2. – Automatic clutch for Taylor & Challen presses.

If the shaft should fail to act, owing to the punch jamming on extra-heavy work, the cam D should be moved back by the hand or foot lever, then with a strip of steel the key F has to be pushed into the shaft, allowing the cam to move over. The flywheel is now run up to speed, the clutch engaged, and the stored energy in the flywheel may overcome the resistance, the crank completing its revolution and coming to rest at the top of the stroke. A one-stroke attachment can be fitted in the form of an extra lever to the right of A. A lug is secured to the crankshaft web, and is timed to push the lever back on the upstroke of the press. This lever in turn moves the striking part of the lever A out of alignment with the projection B on the cam-plate shaft. The spring immediately returns the cam plate

to the off position, causing the press to stop on top dead centre. This action occurs even if the hand lever or pedal remains depressed, and it is necessary to let them go back to normal position before another stroke can be made.

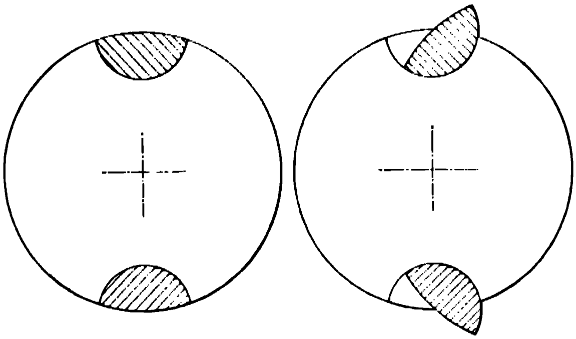


Fig. 3.—Action of clutch bolts on Rhodes' press.

Fig. 3 shows the style of clutch which is fitted to Rhodes' presses, giving complete control of the crankshaft by the flywheel on both the upward and the downward stroke. The bolts open and close simultaneously. When the treadle is depressed, the rod A (Fig. 4) moves upwards, so tilting C and causing its companion lever to swivel the clutch bracket on pin B, releasing the clutch bolt. A stroke of the ram then takes place. The small roller seen on the circular catch-plate strikes the vertical lever C before the stroke has finished, and a second movement of the ram is prevented, even when the treadle remains down. If this roller is removed the press will run continuously so long as the treadle remains depressed. By moving a small lever the clutch can be locked for die-setting, so that a stroke cannot take place.

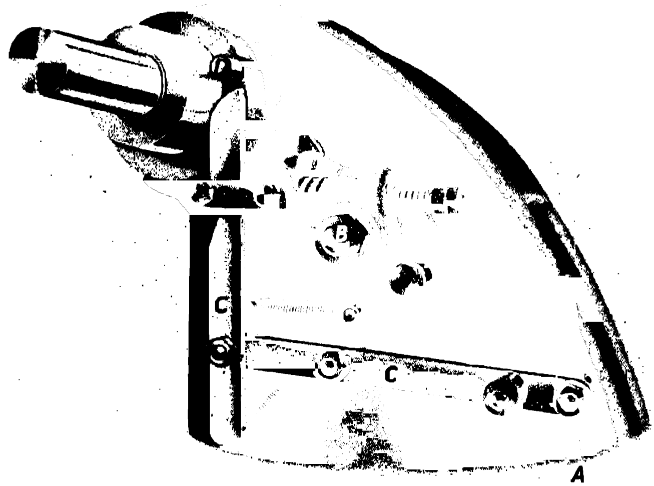


Fig. 4.—Mechanism which controls the Rhodes' clutch.

Adjustable-stroke Device.—When different lengths of stroke are required an eccentric bushing is fitted to the crankpin in such a manner that it can be partially rotated to fresh positions and locked positively. There are various methods of effecting this motion, by toothed locking washers, segmental pads, and curved keys. Fig. 5 represents the second-named arrangement as applied to Rhodes' presses, though the first-named device may be furnished when desired. It has the disadvantage of one-sided transmission which is not present in the style illustrated. Here the teeth are on the periphery and the pressure is balanced.

Taylor & Challen practice is as illustrated by Fig. 6. The eccentric bush A is fixed to the crankpin by a curved key, for which a number of keyways are cut both in the shaft and in the bush. To alter the stroke the set-screws B are slackened, and the end-plate C which prevents the curved key from slipping out is swung away, thus enabling the key to be withdrawn. The shaft and bush can then be turned by means of tommy-bars to obtain the required stroke. Figures are stamped against each keyway on the shaft and bush indicating the strokes, so that when two keyways bearing the same figure are brought opposite each other, and the key inserted, the press will run at that stroke. The end-plate C has to be replaced and the set-screws tightened. Examples of the range in three sizes of machines are: $\frac{1}{2}$, $\frac{3}{4}$, $1\frac{1}{8}$, $1\frac{5}{8}$, 2, and $2\frac{1}{4}$ inches; $\frac{1}{2}$, 1, $1\frac{3}{4}$, $2\frac{7}{16}$, 3, and $3\frac{1}{2}$ inches; and $\frac{1}{2}$, 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, 3, $3\frac{1}{2}$, and 4 inches.

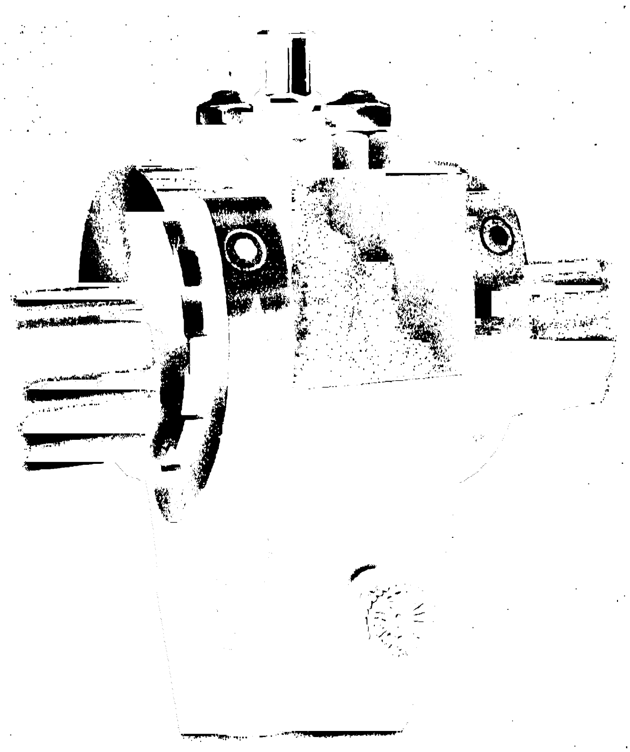


Fig. 5.—Rhodes' adjustable-stroke device.

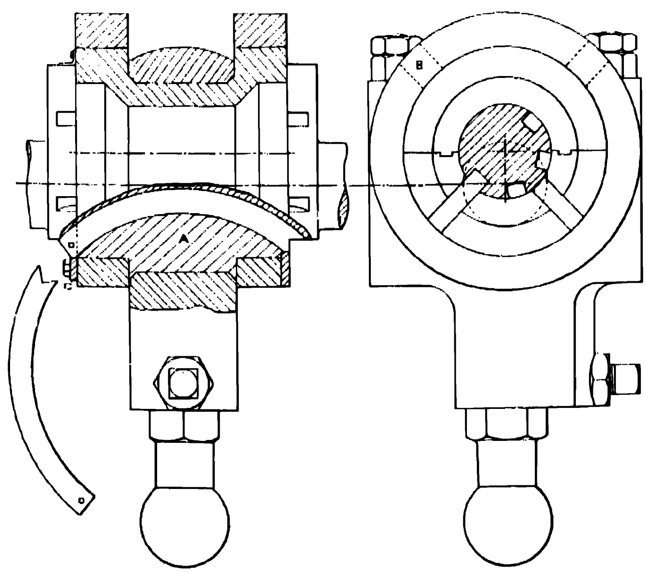


Fig. 6.—Taylor & Challen key-and-eccentric stroke adjustment.

The eccentric adjustment on the end-

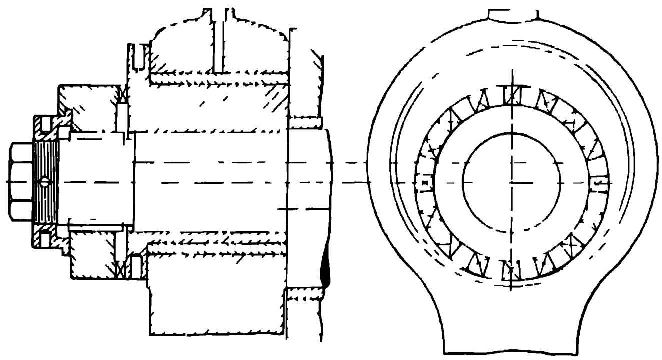


Fig 7 - Stroke adjustment for Schuler end-wheel press

wheel type of press embodies a graduated dial with peripheral notches for locking, and settings to one-hundredth of an inch can be read. For sub-press work a device can be included which gives four definite settings, without affecting the use of the regular adjustment. Fig. 7 requires the toothed locking ring to be retracted by means of the nut to enable the eccentric bush to be turned.

Connections to the Ram.—The connecting rod, or pitman, which transmits the movement from the crankshaft to the ram has to be attached flexibly to the latter, and this is done by means of a ball end on the screw which goes into the pitman and enables the height of the ram to be altered. After setting, the screw is gripped by a split lug and bolts on the end of the pitman, or a loose cap is employed instead of the split lug. A straight-line construction is the best as preventing any tendency to rock, that is, the centre of the crankshaft and that of the hole in the ram should be in line. In some cases, such as those of the end-wheel designs of punching or blanking presses, a simple pivotal connection is made to the ram, without a ball. This is also the case with the heavy presses using eccentrics cast on the wheel hubs (Fig. 8). The double-crank mechanism requires simultaneous adjustment of both ball rods, this being effected by a horizontal shaft and duplicated bevel or worm gears. The shaft is turned by a tommy-bar, or a chain wheel, while a hand wheel is the alternative in large sizes. The biggest presses have a motor for this service ; thus an 18-inch stroke press driven by a 35-h.p. motor has a

Fig. 8.—Gears combined with eccentrics, which give the motion in Wilkins & Mitchell presses

$7\frac{1}{2}$-h.p. motor for the slide adjustment, connecting to the gearing by a slidable vertical shaft, through another with universal joints. Fig. 9 shows a press thus fitted.

Slideways.—Correct design and maintenance of the ram slideways is highly important as affecting the working of dies, and their freedom from premature wear or injury. Ample length should be given in order to reduce the tendency to tipping, otherwise intricate dies cannot be operated accurately. The self-guidance of a wide slide is, however, inadequate, hence the reason for the two-crank and four-crank motions, in conjunction with the four vee-guides placed at the corners of the slide. As a security against the risk of the frame springing, many presses include a round or flat tie-bar attached to the faces of the standards. Instead of the usual practice of bolting the adjustable guide strips to the frame, in some large models they are attached to the slide, so leaving the whole area of its base free for the fitting of large tools. In the machines built up from steel plates, the ram guideways have to be in the form of castings bolted on. Fig. 10 illustrates a very strong "ring" frame of steel, and Fig. 11 another plated construction which has rods as guideways.

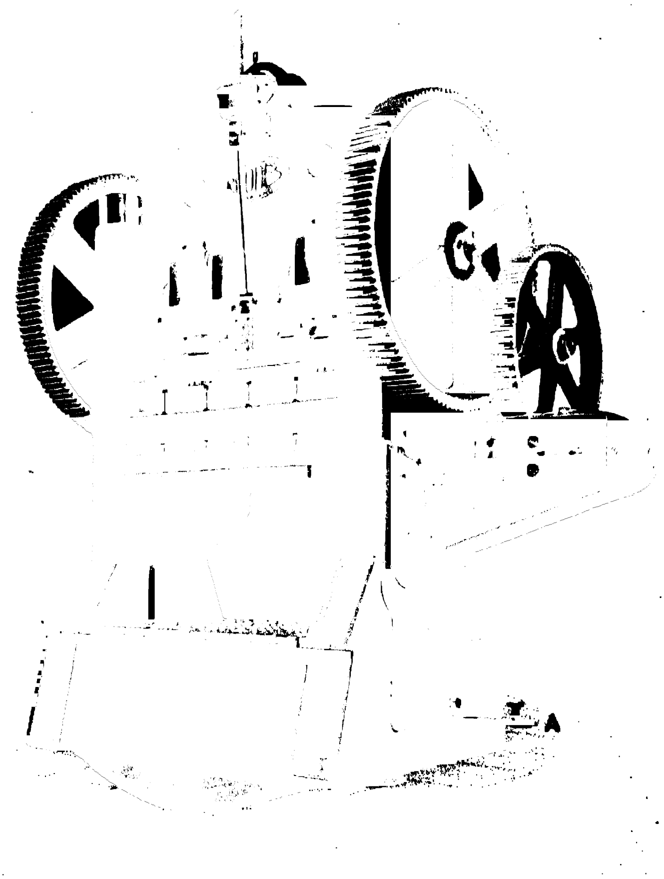


Fig. 9.—300-ton motor-driven press with air-operated multiple-disk friction clutch and air-balanced slide. (Rhodes.)

Counterbalance.—Many of the bigger presses, of 60 tons and upwards, have the slide counterbalanced by a weight or springs or air. This confers the advantages of smooth action, ease in turning the press by hand when setting the tools, and the punch does not tend to suffer by dropping into

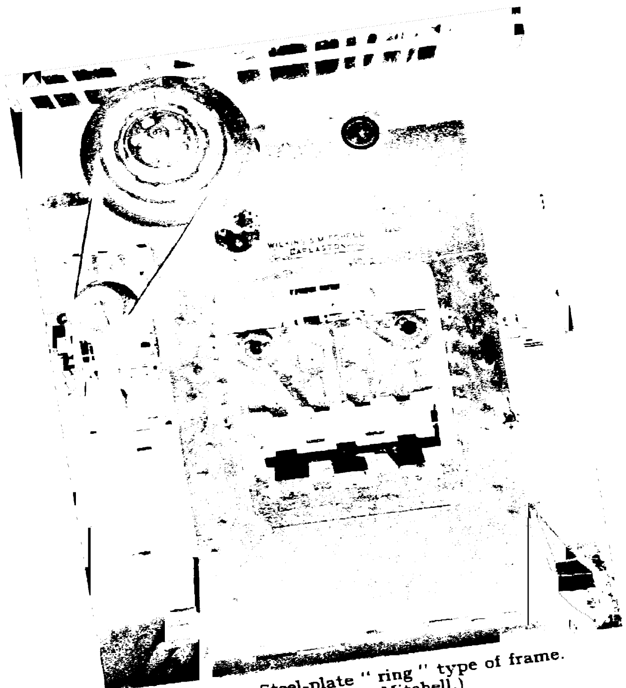


Fig. 10.—Steel-plate "ring" type of frame. (Wilkins & Mitchell.)

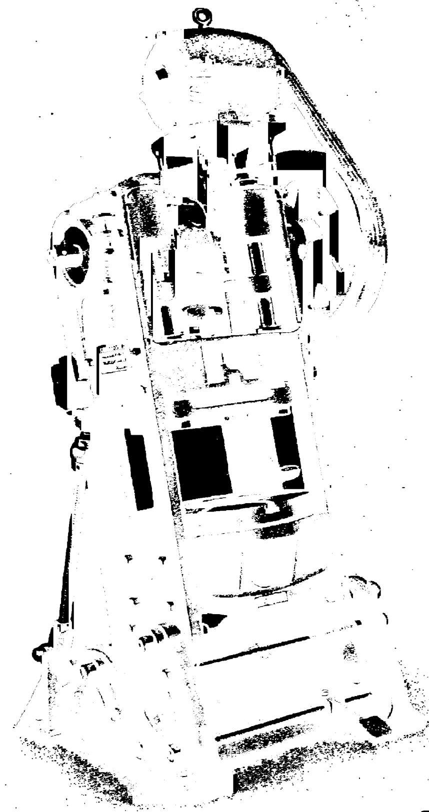


Fig. 11.—High-speed press of steel-plate construction. The openings permit strip feed. (Rhodes.)

the die after the blank has been cut. Several of the Taylor & Challen machines are arranged with rods pivoted at the flanks of the slide, and attached to a pair of rocking levers above the top girder, and the weight is bolted to the other ends of these levers. Another system is that of running cables up from the corners of the slide, over pulleys to a central weight which has only vertical movement. When springs are employed, either two or four casing cylinders stand in front and rear, and rods go down to the slide.

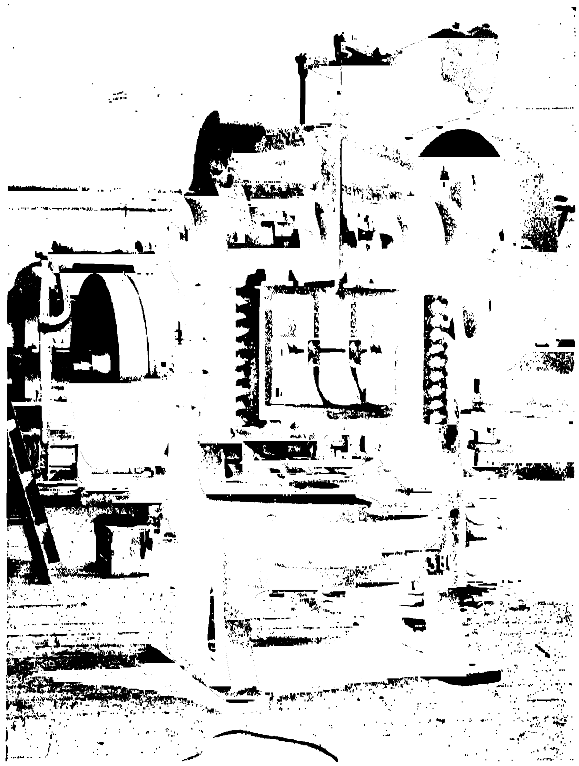


Fig. 12.—100-ton double-crank press with balanced slide.

Beds.—A good deal of variety is to be seen in the forms of beds for blanking presses, and sometimes the faces of the slides are modified in accordance, such as making them specially wide, or flanged square. Standard shapes of beds are square, oblong, or round, with two or more slots to fasten the bolster or other mounting. A round or rectangular opening is made at the centre. The bed is extended by flanges for certain purposes, particularly to sustain automatic feed-roll brackets, and an auxiliary wing may be included to carry straightening rolls. Scrap cutters or scrap winders are other attachments requiring extensions. Poppet screws are fitted to many small presses, and to some of the larger sizes, affording facility for adjustment and fixing, but clamping plates are more commonly employed.

Fittings are located underneath beds for extracting the material after blanking, and also for cushioning the die. The extraction is performed by a spring motion operating a plunger ; or a positive mechanical thrust is obtained by means of side rods reaching down from the ram to a cross-bar through which the plunger is adjusted with nuts or a hand wheel. For large diameters a rising plate is fitted to which the extractor plate is attached. In the case of a double-crank press which blanks and pierces rings 30 inches diameter, three extractor rings are provided, two in the top die, and the lower one is pushed up by a plate lifted by rods as described.

Die-cushions are mounted in the beds of blanking presses when combination dies are used. The cushion supplies a counter-pressure to a ring on to which the blank lies as it is cut, being held with enough friction to prevent puckering. The pressure is derived from a rubber block, or a spring, while hydraulic or pneumatic cylinders are largely utilised. If there is no air line in the shop a self-contained outfit is supplied, consisting of a small compressor and an air receiver.

Applications of Blanking Presses.—In view of the large number of various kinds of blanking presses which are available, descriptions may now be given of the diverse applications of these presses, to enable the user to decide what types to select for certain purposes, and how the tools, attachments, feeding, and other equipment are arranged. As previously indicated, many of the standard designs of machines are suitable for a considerable range of duties without modification in the framing or bed, and a special bolster bolted to the latter affords flexibility in arranging dies and other details. It should be mentioned that the T-slots in the bed should be machined out, so that the hold-down bolts take a proper bearing and keep the dies always fixed truly. The bolster ought also to be of substantial form and ample area to withstand the severe pressures to which it is subjected. Quite a lot of specialised mounting can be done by using a thick and enlarged bolster, but, of course, there are numerous instances in which it is essential to have the bed of widened pattern. The open-fronted design often lends itself more freely to this kind of modification than is the case with the double-standard type. Sometimes the tie-rods can be removed when it is required to pierce sheets of large area, and thus avoid the necessity of using a bigger size of press.

Capacities of Small Presses.—The small bench or stand machines are capable of exerting 1 to 2 tons pressure, the latter force being capable of blanking a disk in mild steel $1\frac{1}{2}$ inches diameter by $\frac{1}{32}$ inch thick; or $\frac{3}{4}$ inch diameter by $\frac{1}{16}$ inch thick; or 5 inches diameter by ·01 inch thick. The performance of a 6-ton press on similar material is: 7 inches diameter by ·02 inch thick; or 2 inches diameter by $\frac{1}{16}$ inch thick; or $\frac{1}{2}$ inch diameter by ·128 inch thick.

Medium Powers.—The medium range of pressures, from 12 to 20 tons, may be specified, and, for instance, a 12-ton press will blank in mild steel 9 inches diameter by ·02 inch thick, or 3 inches diameter by $\frac{3}{32}$ inch thick; or cut and form a cup in $\frac{1}{32}$-inch thick steel 3 inches diameter by $\frac{1}{2}$ inch deep. A 20-ton press will blank 11 inches diameter in ·025-inch thick sheet, while a similar power when employed for work of large area cuts 24 inches long by 3 inches wide in ·022-inch metal.

Higher Powers.—A 40-ton machine cuts 12 inches diameter through ·048-inch metal, or 2 inches square through $\frac{1}{4}$-inch thick plate. At 60 tons pressure, a disk 13 inches diameter by 15 s.w.g. thick may be blanked. The big double-crank presses possess great power, together with large

bed area ; thus, one of 150 tons pressure cuts a blank 48 inches diameter from a sheet 72 inches square and ·048 inch thick, and another of 200 tons capacity blanks to 60 inches square.

Specification of 10-ton Press.—In order to give an idea of the proportions of a small power press, the following particulars of a Taylor & Challen geared model may be cited. The gearing gives a slower motion to the punch than is the case with the ungeared type (which is otherwise similar), hence thicker metal can be blanked, or cups can be extended. It should be understood that the pressure rating refers to that applied near the bottom of the stroke, the pressure being less effective when drawing is done, as the work is spread over a longer period.

Pressure exerted at bottom of stroke	10 tons
Stroke	3 to 4 inches
Strokes per minute (usual)	50
H.P. and revolutions per minute of motor	2 h.p. at 950 r.p.m.
Angle of inclination (maximum)	30°
Diameter of crankshaft journals	2 inches
Diameter of crankpin	2¼ inches
Bed to slide (adjustment up stroke half-way down)	8¼ inches
Adjustment to slide	1½ inches
Width between slides of frame	8¼ inches
Width between extractor horns	9¼ inches
Depth of throat	7 inches
Bed, right to left	23 inches
Bed, front to back	13 inches
Hole through bed	9¼ inches
Width of T-slots	1⅛ inches
Slide base, right to left	5 inches
Slide base, front to back	5⅝ inches
Diameter and depth of recess in slide (standard)	1¾ inches diam. by 2 inches
Floor to bed	34 inches
Floor to crankshaft centre	56 inches
Overall height	69 inches
Net weight (excluding motor)	21 cwt.

Specification of 350-ton Press.—In contrast to this machine, the data regarding a 350-ton double-crank press may be quoted :

Stroke	18 inches
Strokes per minute	14
H.P. of motor	35
Speed of motor	1,000 r.p.m.
H.P. of motor for slide adjustment	7½
Diameter of crankshaft journals	10 inches
Diameter of crankpins	11 inches
Bed to slide (stroke and adjustment up)	44 inches
Adjustment to slide	3 inches
Width between uprights	66 inches
Area of Bed	
Right to left	66 inches
Front to back	54½ inches
Thickness of bolster	6 inches
Hole in Bed	
Right to left	50 inches
Front to back	34 inches

Area of Slide Base	
Right to left	65 inches
Front to back	42 inches
Floor Space Overall	
Right to left	151 inches
Front to back	116 inches
Height	190 inches
Weight (including motors)	49 tons

Choice of Press.—The selection of a press for a specific purpose depends, as will be evident from some of the notes in this chapter, on the force required, the area of the sheet to be blanked, its thickness, whether a cupping operation is necessary, and if hand or automatic feeding has to be done. Many of the open-fronted presses afford ample capacity as regards area of bed, but may not supply the essential rigidity to work intricate tools which will endure for a long period, and turn out stampings true and interchangeable. The question should be considered, therefore, whether for the more difficult kind of job a double-sided machine is to be preferred. When dealing with thick or tough metal it may be much more economical to use a press of this type.

Hand or Automatic Feeding.—The choice of either of these methods of passing the stock to the dies may in certain instances affect the selection of a press. A large proportion of the objects stamped from strip are thin, consequently the open-fronted, auto-feed press is generally a suitable type to employ. But for a good many drawing operations the double-sided pattern is preferred. Hand feeding is adopted extensively for small lot production, and also for shapes for which it is not convenient to rig up an automatic feed, while, of course, there is a lot of large stuff which can only be supplied by hand to the dies. Some of the secondary processes performed on stampings necessitate hand feeding, unless large numbers warrant the employment of auto-feed mechanism. The inclined position of a press often facilitates hand placing.

Automatic Roll-feeding Systems.—Blanking of large numbers from strip or sheet warrants the use of a semi-automatic or fully automatic feed, and there are several kinds of apparatus which take raw or partially treated units and transport them to the die. Taking a survey of the various methods, that of feed by means of rollers is applied very extensively. It assures safety to the attendant, maximum output, and reduction of scrap to a minimum. In the case of successive "or follow-on" operations the various tools are spaced one, two, three, or more feeds apart, and if exact equality is required, centring is employed or pilot pins may be fitted to locate the strip, such as in the manner seen in Fig. 13, or side punches may be arranged, to leave projections on the strip (Fig. 14), which abut against raised edges on the die, and act as locating stops. The feed rolls give a slight excess motion so as to ensure this stop action. The black outlines indicate the punching at one operation, and the dotted outlines what is performed after feeding forward one pitch.

Roll feeds may be either single or double, the advantage of the latter type being that scrap is reduced to the minimum, as when the leading pair of rolls have fed all they can, the others take control. The features of the mechanism comprise a ratchet or friction feed, gearing to vary the feed ratio, and a relieving device to permit the strip to float when

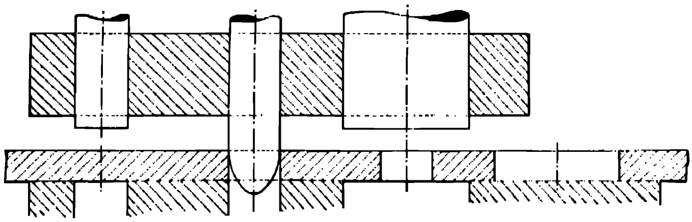


Fig. 13.—Pilot-pin method of centring pierced hole before blanking.

accurate location is desired in the way just described. Hand lifting is also necessary for the purpose of inserting the stock. The feed travel varies, in different presses, from a maximum of 1 inch in little machines to a maximum of about 15 inches—this in a press which blanks large disks. Transmission of the motion from the crankshaft is by means of a crank

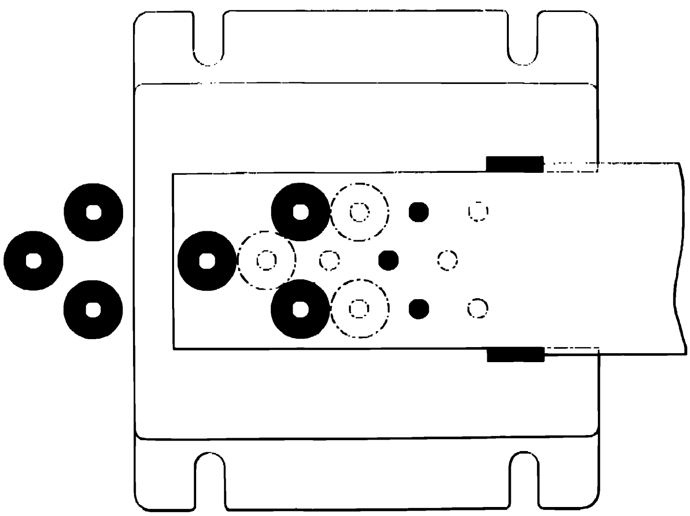


Fig. 14.—Mode of piercing and blanking washers from roll-fed strip.

disk on the end of the crankshaft, thence to a ratchet wheel, friction wheel, or free wheel, the two latter devices permitting of fine adjustment of the crank-disk throw. The ratio of movement from the crankshaft is varied by bevel gears, as 1 to 1, 2 to 1, or 3 to 1. A higher speed can be given to the outgoing rolls, to compensate for the lengthening and sagging of the strip after punching. In one design the roll brackets are pivotally attached to the table, and can be swung out of the way for die-setting, or hand feeding.

Stock Control.—The coil carrier that stores the strip consists of a stand carrying a bracket adjustable for height, and this has a disk with four slots in which rods can be adjusted radially to suit the size of coil, held on by a spider, the hub on which the carrier rotates having ball bearings. A simpler equipment consists of a reel bolted to the end of the feed-roll support, and having flanges adjustable for width apart. A similar reel driven by a chain can be mounted at the opposite end to wind off the scrap (Fig. 15). Another kind of winder has a separate stand, the spindle being chain driven from the feed-roll shaft on the press, and revolving the winding drum frictionally to allow for the increasing diameter of the coil. The drum is grooved so that the coil of scrap may be wired before removal.

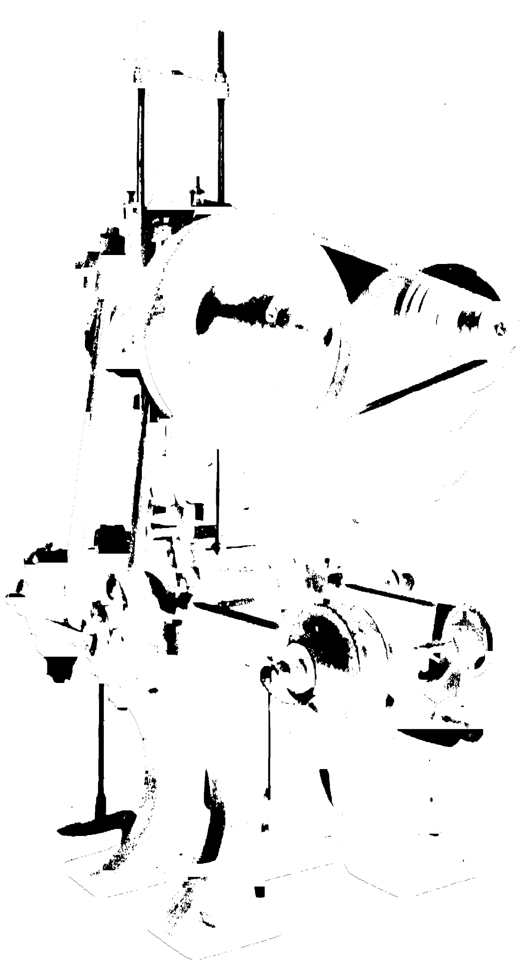


Fig. 15.—Equipment for washer production, double roll feed, and scrap winder. (Taylor & Challen, Ltd.)

Straightening Rolls.—To straighten the strip metal a set of rolls is mounted on a separate stand adjustable for height, or it may be bolted to an extension table at the side of the press (Fig. 16). Five rolls effect the straightening, the two top ones being lifted by a lever to enable the strip to be started in. Wide stock is drawn through the straightening rolls by two pairs of feed rolls, with or without feeding-out rolls.

Scrap Cutter.—A good many presses are equipped with a scrap cutter (Fig. 17), which severs the blanked strip and delivers it into a box. When round holes are punched through fairly wide strip the scrap can be sheared through the narrowest sections, and the resulting pieces be used for stamping small articles.

Cutting to Length.—A different reason for cutting after a punching operation is to get pieces to dead lengths. A Taylor & Challen double

Fig. 16.—Schuler blanking press which has straightening rolls, double roll feed, and scrap cutter.

Fig. 17.—Double roll feed and a scrap cutter are fitted to this press.

press is built with duplicated frames and one flywheel pulley driving the crankshaft. The strip is fed to a table at the left-hand press, passes through the first pair of feed rolls, and is pierced with a number of small holes. Then it goes through the second pair of rolls to the other press, where cutting-off tools sever it, leaving as many holes in the unit as may be required. The length of strip cut may be varied by substituting different ratchet wheels and so altering the feed length.

Gripper Feed.—This is an accurate mode of propelling the stock against a stop. Two grippers are provided on the inlet side and two on the outlet side for feeding and clamping the material (Fig. 18). When working with pilot pins the holding grippers can be lifted just before the stamping operation takes place.

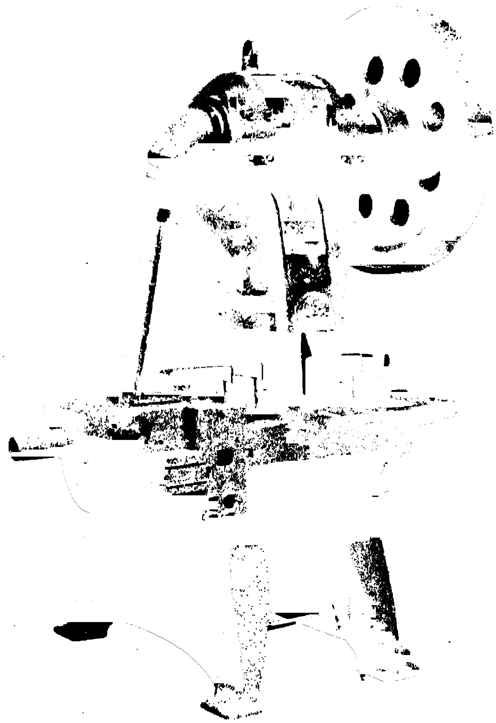


Fig. 18.—Gripper feed on a Schuler press.

Slide Feed.—Raw material, as well as partly finished articles, are often handled by a slide mechanism. In the simpler forms there is a slide which moves the piece to the dies, and ejects and pushes them off without the operator's hands coming near the dies. The slide is actuated by hand, or mechanically. More elaborate construction is noticeable in feeds for presses which produce blanks, punch apertures, or make large numbers of holes at high speed. An example of the latter class of work occurs on a press that punches square holes along the edge of a strip, 25 inches by 12 inches, which is held by grippers to a feeder rail, and propelled intermittently. The stop motion can be set to leave a space between the openings equal to two, three, or more pitches, and the rate of punching is 120 per minute. A press incorporating slide feed for multiple blanking operates eleven punches, placed in staggered fashion, to leave the least quantity of scrap from the strip. An adjustable stop screw determines the amount of feed, and springs bring the feed slide back to this stop after each stroke. Spring rollers guide and prevent the strip from moving back with the feeder slide. A gripper pivoted to the slide clamps the strip to feed it forward. Fig. 19 shows the application of a slide feed on multiple-die work.

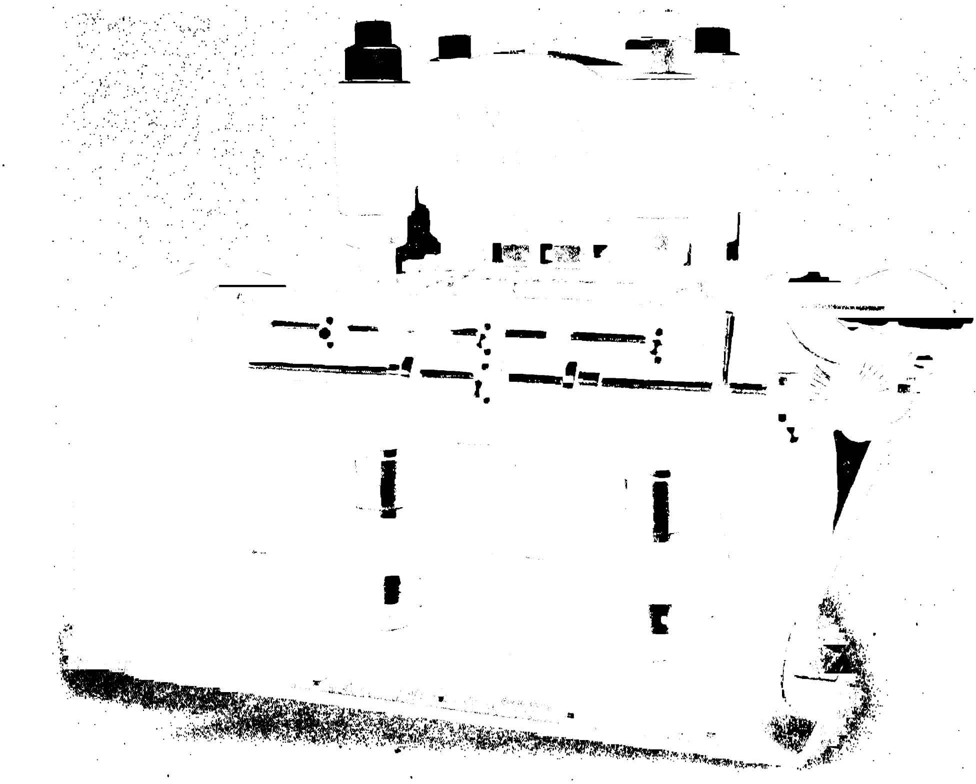


Fig. 19.—Slide feed on multiple-die automatic press.

Preparation of Scalloped Strips.—The highest rate of blanking is performed on the multiple-die presses, and those which operate a stagger feed under one punch. The sheet or strip is fed by grippers and slides so as to utilise every possible square inch. Two systems are employed for high-rate production, the first that of punching out the blanks in zigzag formation from a whole sheet, and the second that of shearing the sheet into strips with scroll or scalloped edges conforming as closely as possible to the contour of a row of circles (Fig. 20). For this latter service a special scroll-shearing machine is used, combined with a rotary slitter. The

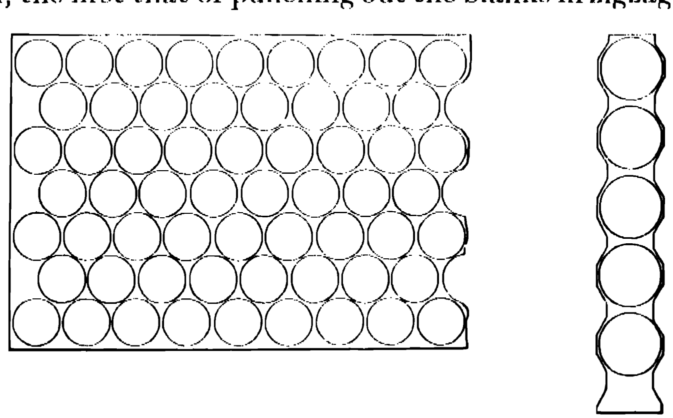


Fig. 20.—Staggered system of blanking, and scalloped strip.

sheet has to be placed against gauges on the table of the slitter, and dogs on two feed bars pick up the sheet and deliver it to the rotary cutters, which trim both sides straight and parallel. It then falls on to the table of the guillotine shear, where the fingers of a set of reciprocating feed bars place it under the specially shaped blades of the shear. Two pairs of scalloped blades are required for cutting single-row strips, so that one strip falls to the rear of the outer blade, and the other in between the blades. One pair of blades is necessary for double-row strips. The stroke of the feed bars is adjusted to be a trifle longer than the width required for a strip, and the sheet is consequently fed past adjustable stop gauges on the table. On the return stroke of the feed bars the sheet will be carried back, then stopped and stripped from the feed fingers by the stop gauges. As these latter are set to the exact width of the strips to be cut, uniformity of all strips is ensured.

Blanking the Strips.—Finally the strips are automatically transferred to the press, leaving the scrap stacked at the shearing machine. The strips lie in stacks on the left-hand front table of the press, from which they are lifted singly by four suction rubber pads, operated by an air pump. The automatic feed apparatus embodies two pushers that thrust the strip rapidly towards the back of the press (the vacuum being broken at the same moment), and under the fingers of the feed bar, which has a reciprocating movement to and from the die. The feed fingers are spaced along the feed bar at intervals corresponding to the pitch of the centres of the blanks to be stamped at each stroke. At each stroke of the feed bar towards the die the last finger on the feed bar, nearest to the left side edge of the strip, pushes it under the die. The feed fingers thus work consecutively, starting with the first finger on the left-hand end of the feed bar. After the last blank has been cut, a kicker throws the scrap into a box. In the event of a strip jamming, an electrical attachment stops the press. This sort of shearing and blanking equipment is made by the Bliss Company.

Stagger Press.—This class of feeding involves supporting the sheet on a large table which is fitted with adjustable apparatus to pitch the distances as required (Fig. 21). The alternative methods are: to use an interchangeable longitudinal dividing bar, and adjustable cross-notches, or adjustable longitudinal and cross-dividing notches. The main purpose of the presses that produce blanks by the scallop or the stagger system is that of producing lids and bottom of cans and boxes of all sorts from tinplate or other thin material, but machines are also built for heavier work. A heavy, geared, automatic stagger press, for instance will blank sheet of 16 s.w.g. to 6 inches diameter ; it will also do drawing.

Dial Feeds.—A turntable supplies a mode of continuous feeding of units without risk to the operator (Figs. 22, 23). It is difficult to differentiate between the uses for blanking and piercing and those for drawing, embossing, necking, lettering, marking, and many other processes, because

in many cases the principle is the same. The dial can be employed in two different ways, either to act as a carrier for placing successive pieces over a die, or to hold a set of dies, which in turn bring the part under the punch.

The partial rotation is effected from a crank disk on the end of the crankshaft, or by mitre gears thereon, thence to a ratchet wheel or friction band on the turntable. Or an escapement movement is utilised with indexing and locking from a vertical shaft. Other methods of locking are adopted, such as cam-actuated transmission from the crankshaft working a stop for the indexing positions.

An exception to the usual practice of having stations to the dial may be observed on a press with mixed feed arrangements. The dial has a plain, smooth face, and the components are laid on it, to be swept around intermittently to a cam-operated pusher that feeds them into position over the die.

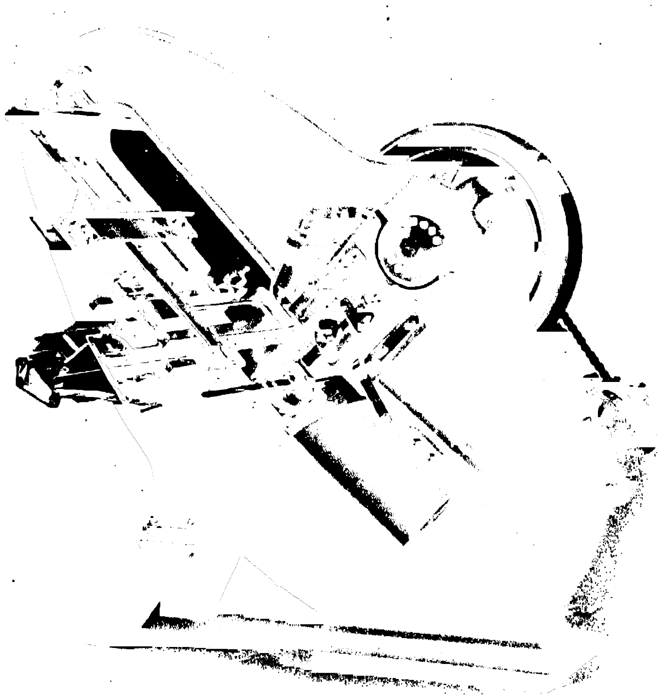


Fig. 21.—Rhodes' automatic stagger-feed press for high production.

When objects must be taken over the die, this is accomplished by means of a carrier plate fastened on the dial, the plate having holes or recesses of suitable shape. Another scheme is that of making holes in the dial for the reception of jigs. The number of stations varies according to the diameter of dial, and the size of the work, as many as forty being used for small pieces.

Applications of Dial Feeds.—Among the numerous interesting uses of these feeds, the following may be noted: the simple operation of flattening washers and links, etc., is performed from a turntable holding ten dies on to which the articles are placed. A stationary die directly under the centre of the ram supports the dial against the pressure of the flat-ended tool which gives the pressure, and an automatic wiper then clears the flattened pieces from the dial. For flattening, piercing, and shearing the corners of brass cable clips of long strip shape, the carrier plate has sixteen grooves, into which the clips, with the ends folded

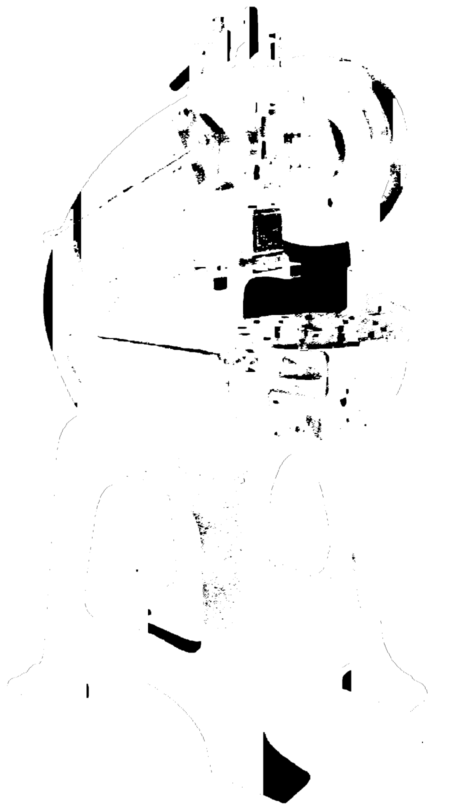


Fig. 22.—Light press equipped with twelve-hole turntable. (Taylor & Challen, Ltd.)

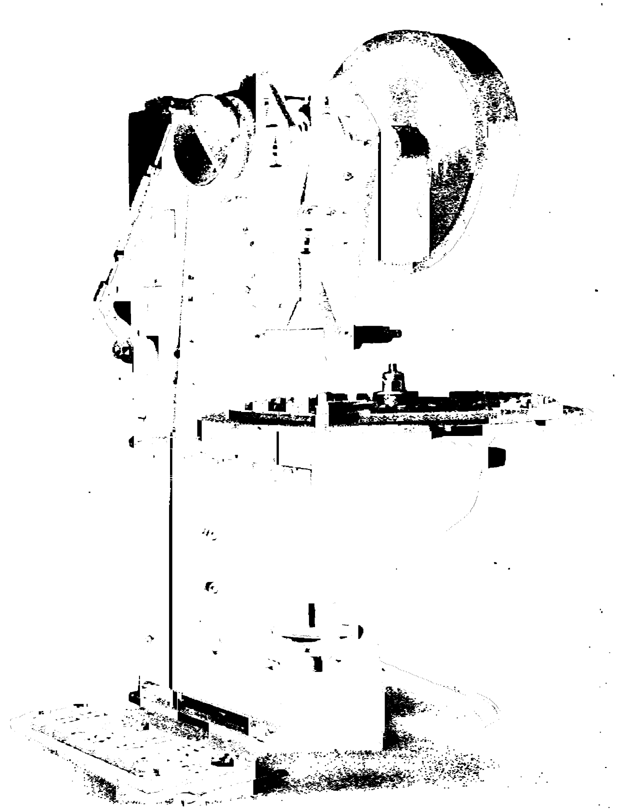


Fig. 23.—Dial-feed press of fabricated construction. (Rhodes.)

over, are placed, and gripped by spring-pressure buttons. On the centre line of the press there is a double set of tools, both sets working simultaneously on two clips. One set does the flattening, the other set pierces two holes and shears the corners to 45°. The turntable is relieved from pressure, as the ends of the clips project from it.

Some objects are placed on pegs fixed in the dial, or secured to it by screws and clamps. Cups may be dealt with in this manner, to be flattened, pierced, lettered, or embossed. In certain cases the die is located in the press ram, and the circle of punches on the turntable; after dropping a cup on a punch it comes under the die and is necked, then an extractor pushes it out of the die and lets it fall loosely on to the punch, from which the attendant can later remove it.

Perforating Feeds.—An intermittent motion indexes lamp galleries, air-regulator thimbles, lamp-wick carriers, strainers, and various kinds of tubes for the piercing of sets of holes, round, square, oblong, or contoured. Sometimes the support on which the part is mounted revolves, but where, for example, small thimbles are pierced, these are rotated intermittently upon a stationary support through the medium of gears. Clamping by a pallet pressing the piece tightly upon a formed mandrel on the spindle which does the indexing is observable in the production of a lamp gallery. Part of the operation consists in blanking out portions to leave the prongs at the top, and another setting pierces air holes in the lower part. For parallel tubes a long bolster is attached to the press bed, and has at the right-hand end a round horn on which the die is mounted. Opposed to the horn is a pallet plate on a spindle thrust along by a lever motion, and the tube becomes gripped between the pallet plate and a flange on the horn, both plate and flange turning on ball bearings. Ratchet feed from the crankshaft revolves the pallet plate spindle.

Tube Feed.—Small articles sometimes lend themselves to feeding by tube or magazine, in which they are placed by hand, or fall from a hopper. Transference to the dies takes place by slide, and there may be a spring gripper included which holds the blank until the time comes for it to be transferred, thus preventing false movements. Hopper and tube feeding occurs in a press for flanging and piercing small cups. They are dumped into the hopper, from which they are fed by pegs down a vertical tube, from the bottom of which a slide moves them to the die. The press stops automatically should a cup happen to get upside down. A combination of a tube supply with gripper feed affords an alternative for pieces to be pierced, embossed, or otherwise pressed. The tube, inclined or vertical, drops the parts where the hinged gripper fingers take hold and effect the transference to the die. On the return stroke the fingers open to miss the piece just fed (Fig. 24), and at the end of the travel take hold of the next blank. When the time comes to pass this to the pie it pushes off the unit just pressed.

Magazine Feed.—Some of the horizontal presses have a magazine type of feed down which the work slides or rolls into position. A composite

arrangement on a vertical press has a magazine from which the parts go to a push feed. As the stroke of the ram in this machine happens to be short the speed of the push feed has to be accelerated, which is done by using elliptic gears for the connection from the crankshaft.

Die Slides.—A practice sometimes followed for both small and large presses is to put the die upon a slide, drawn out to emplace the work, thus avoiding danger to the operator. In some cases there is not much room for the attendant to reach to the die, and this is another reason for utilising the slide. A little bench press thus fitted has the slide moving between shouldered gib strips, and reciprocated by cam and lever from the crankshaft. A similar mode of moving the slide is adopted in some large presses. In another example, a pneumatic cylinder retracts and returns the die slide to a stop, the air valve being hand controlled independently of the ram strokes. Handwheel and racking gear furnishes yet another way of moving the slide, and a safety stop bolt is provided so that the treadle which starts the press cannot be moved until the die slide has been locked in the correct position.

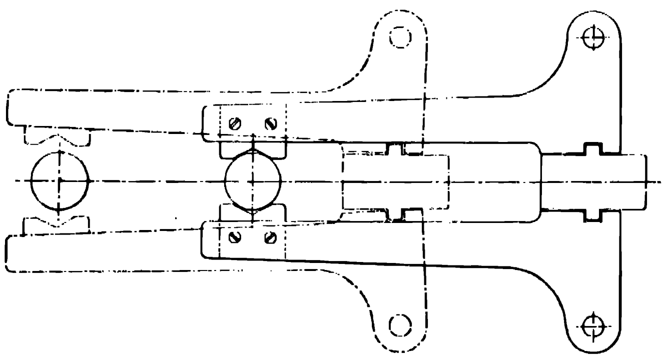


Fig. 24.—Feed fingers which receive piece from a feed tube, and transfer it to the die.

Hot Brass Pressing.—A branch of press work which has developed extensively, and is comparable with blanking, is the stamping of all sorts of shapes in hot brass, to avoid machining, or reduce this to a minimum. The alloy is consolidated by the process, wastage in scrap is largely reduced, and sizing is uniform, powerful double-sided presses being employed (Fig. 25). A great many forms require the use of split dies, which have to be opened for the removal of the pressing. The tools necessary include a vice and side slides, and sometimes a bottom slide. The split dies are opened by these means. The motion to the vice is toggle actuated, worked by a cam on the crankshaft, through links and levers, the side slides moving transversely in conjunction with the main slide. As the press ram descends, these enter each side of the die space, thus forming cores over which the pressed articles are extruded. The bottom motion is worked by links and levers from a crankpin on the end of the crankshaft to an eccentric shaft that operates a connecting rod and slide moving vertically. A punch can be fixed in this slide, and as the main slide descends the bottom motion slide ascends and enters the die space, so forming a core over which the pressing is extruded (Fig. 26). The vice may be opened and closed by hand to hold the hot blank in place until the

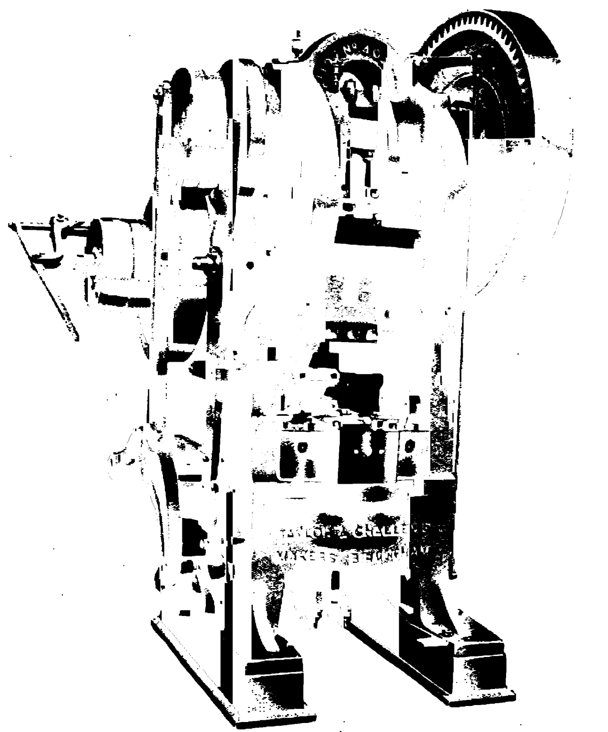


Fig. 25.—Press for hot brass work, all the movements being automatic.

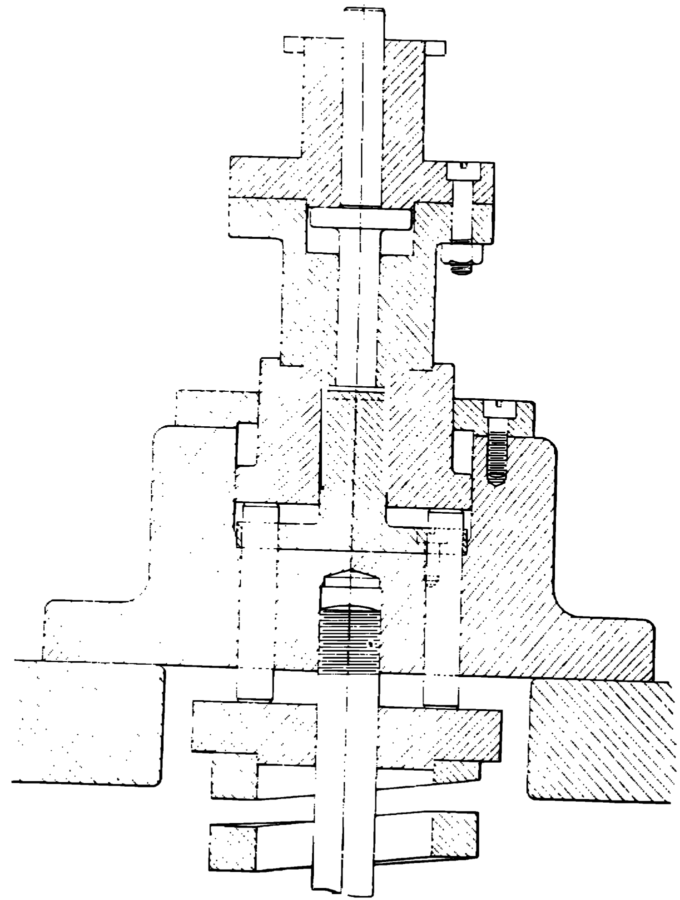


Fig. 26.—Die used for hot brass work. (Taylor & Challen, Ltd.)

press is started, and the power closing takes effect. A spring-controlled collar keeps up strong contact with the top die whilst the pressing is being done, and prevents escape of flash. Extractors are necessary to eject the piece.

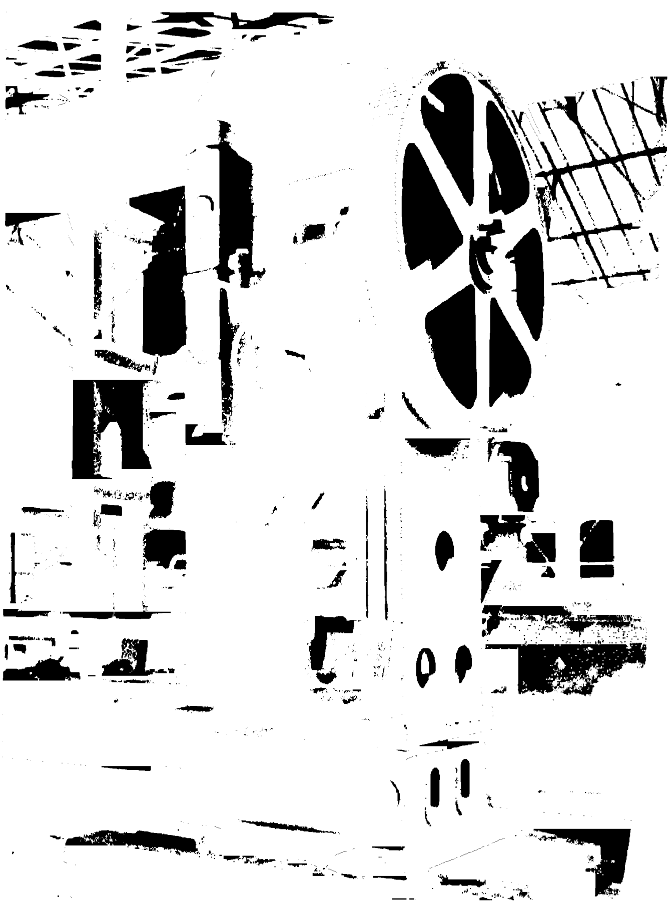


Fig. 27.—Built-up press which has motor and electro-pneumatic clutch drive. (Cowlishaw, Walker & Co., Ltd., Stoke-on-Trent.)

The dies have to be kept hot all the time in order that the brass shall not be cooled by coming into contact with them; for this purpose a ring gas-burner surrounds them, and this is always kept going. At first a substantial slab of hot iron is placed on the lower die, and the upper one brought down to touch it. The billet to be pressed has to be heated before insertion, to fairly near the melting-point. Presses for this class of work are of about 100 tons power.

The steel from which the dies are made contains from 14 to 16% tungsten, and 28 to 32% carbon. It is heated to between 1,150° and 1,200° C., and quenched in oil. It is tempered in air at approximately 600° C.

Some of the data concerning the press illustrated in Fig. 25 are:

Pressure exerted at bottom of stroke	100 tons
Stroke of punch	8 inches
Stroke of vice slide	3 inches
Stroke of side slides	2 inches
Stroke of bottom motion slide	3 inches
Strokes per minute, usual	60
Adjustment to slide	3½ inches
Width between sides of frame	24 inches
Slide base, right to left	22½ inches
Slide base, front to back	10½ inches
Space in dies, when vice is closed	6 × 6 × 6 inches
Power required	10 h.p.

Systems of Driving Presses.—Finally, consideration may be made of the different ways of supplying the driving power, more variety being noticeable in this respect of late years. The motor drives have partly supplanted belting transmission from a line shaft, and a further development has been that of replacing flat belts from motor to crankshaft pulley by rubberised multiple vee-belts. Very short centres are thus possible, and many of the motor mountings are close to the crankshaft, such as high up on the back of the press. A hinged tensioning arrangement

Fig. 28.—300-ton blanking press, double geared and driven by multiplate external friction clutch. (Hordern, Mason & Edwards, Ltd.)

enables the motor to be set farther away as necessary. A good many presses carry the motor at the side, on a facing of the standard, or on a horizontal bracket, and on the large double-standard machines a convenient location is at the top of the cross-girder. Another system is by chain drive from the motor to a first-motion shaft and thence by pinion to the gear on the crankshaft, while double-reduction drive entirely by gears is also employed. Fig. 27 affords a good example of electric driving, with V-rope from the motor to the flywheel. The electro-pneumatic clutch is controlled by a rotary timing disk driven by the crankshaft. Push buttons control the operation of the press, these being located in a convenient position at the front. Fig. 28 gives an

idea of a pulley-and-clutch drive on a press for heavy blanking. A motor may be substituted—20 h.p. is required to drive the press.

The conditions of press driving demand a motor possessing the highest possible overload capacity for a short period, with maximum speed reduction. There is a difference in the energy requirements in blanking and drawing. Blanking is completed in a very brief portion of the press stroke, and the flywheel supplies nearly all the energy required to send the punch through the metal. The motor then takes the rest of the cycle to bring the flywheel back to full speed and energy. But in drawing operations the work is more prolonged and the motor has to sustain a considerable overload.

CHAPTER 2

DRAWING PRESSES

THE term " drawing press " is a rather elastic one, because a good deal of drawing is done on the blanking presses, but specifically it means a design which has double action, a central ram moving the punch, and an outer slide forcing down the blank-holder which grips the blank with sufficient friction to enable the drawing to be accomplished without tearing the material or allowing it to wrinkle unduly. It is possible, however, to employ a single-action press for deep drawing by fitting a device to the table which supplies this pressure automatically, and some of the extending presses are of single-action type. The action in drawing differs from that of blanking, where the greatest pressure is concentrated for a very short time as the metal is sheared, whereas in drawing the pressure must be sustained. Still more severe work is entailed when an ironing process takes place, *i.e.* when the object is drawn and also compressed in order to obtain a finish, or produce uniformity of thickness, or make tapered walls. These essential differences affect the designs of some of the presses, as regards strength of the parts, driving power, and length of stroke. Shallow drawing does not involve any difference in the last-named respect, but deep-drawing types will attain a length of stroke of as much as 30 inches.

Combined Blanking and Drawing.—Comparatively shallow articles can be made with combination tools on the blanking presses of ordinary or multiple-die types, and on drawing presses proper, the same principle being often adopted. Alternatively, the blanks are stamped separately, and transferred to the drawing press. Another procedure is that of blanking with the first stage of drawing, followed by one or more stages in redrawing, the work being distributed between two or more presses, depending upon the plant available, or the numbers required. Extending or reducing is an operation sometimes performed without the use of a blank-holder, one of the chief applications of this process being to cartridge and shell cases, etc., where the wall has to be thinner than the bottom ; the punch pushing the partially drawn piece through the die, the press being of the simple vertical or horizontal long-stroke type.

The usefulness of a single-action press for a general range of operations, as well as for cutting, makes it a very favoured machine to employ for drawing. This is especially the case when moderate numbers of pieces are required, because it can then also be used for blanking, piercing,

bending, and other processes. The die-cushion, or the Rhodes' Simplex drawing device, also converts a single-acting press into a drawing press, and owing to the nature of the mechanism a short stroke will produce a deep stamping. The added complication in the driving mechanism of a double-acting press tend to make it a slower machine in working than is the case with the simpler design.

Blank-holding Pressure.—The degree of pressure required to hold a blank depends upon many factors. The primary object is that of preventing wrinkling, but the resulting elongation of the article has to be considered. The quality and state of the metal, its thickness, the shape,

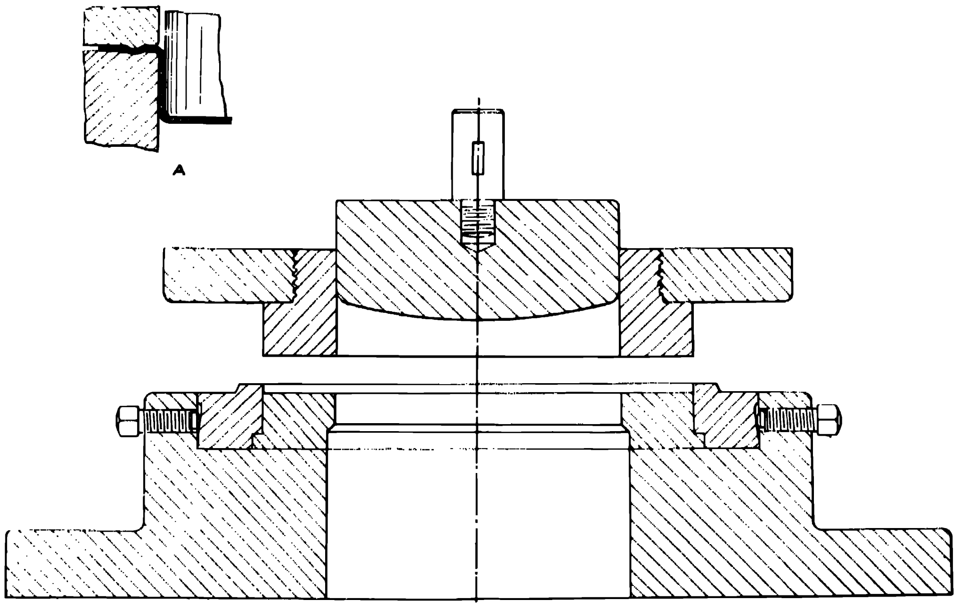
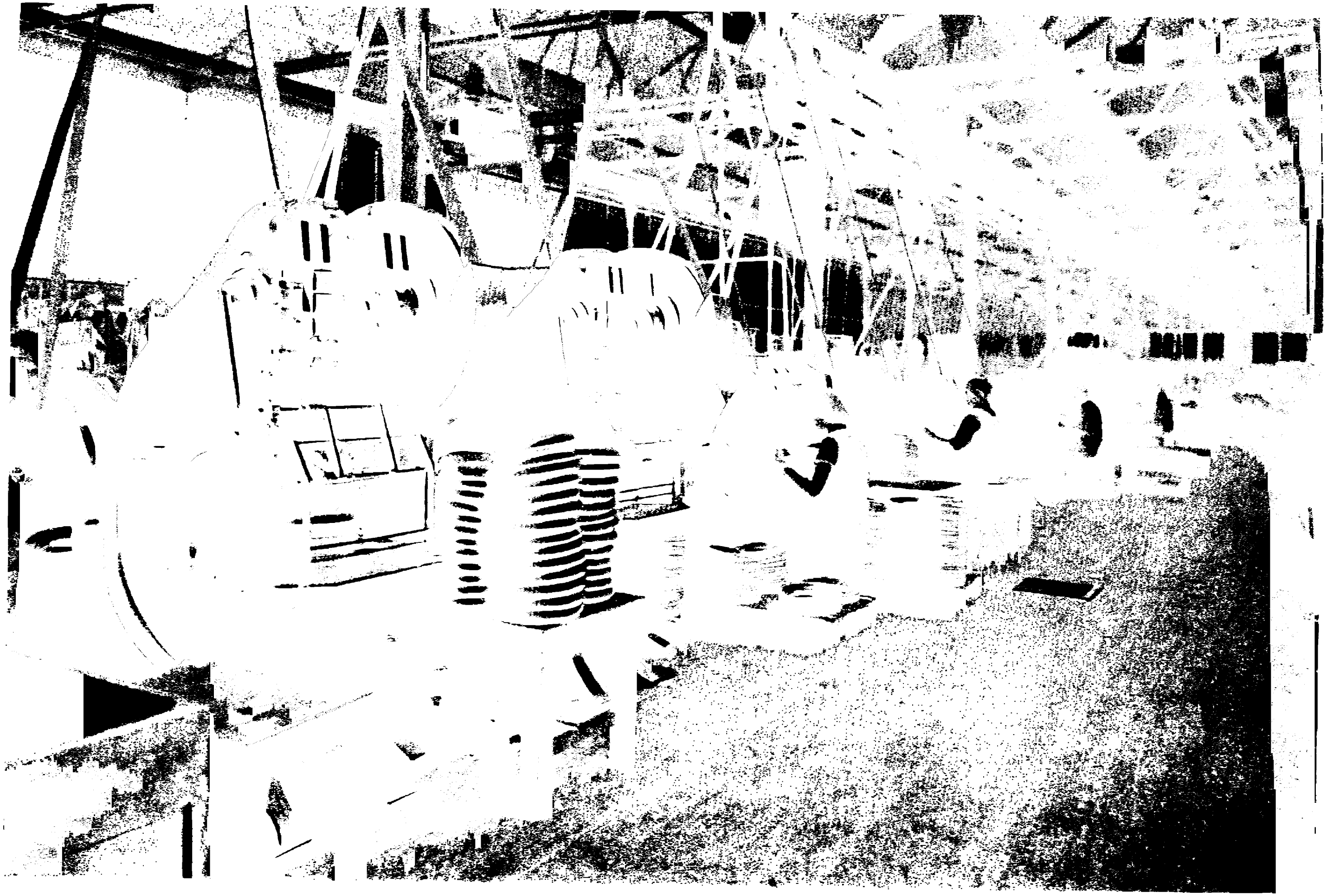


Fig. 29.—Combination die for blanking and drawing. A, Beading, to increase the holding power of a blank-holder.

and depth of draw all affect the problem. A blank will only endure a maximum amount of elongation at each draw, therefore the blank-holder pressure should be as low as practicable, consistent with securing freedom from wrinkling. If the pressure is needlessly excessive the sheet will tear, or more annealings will be necessary between the various stages. The relationship of blank-holding pressure to drawing pressure varies considerably, according to the shape of the work. A very shallow form will not require much drawing pressure, but must be gripped tightly at perhaps two or three times the drawing load. But for deep drawing the holding power will need to be less than half that required for the drawing. A mode of increasing the holding power for a given press is to bead the die and blank-holder faces next to their inner edges (Fig. 29 A), so that the sheet has to be dragged through the obstacle during the operation. The



LINE OF PRESSES AT THE WORKS OF THE VALOR CO., LTD., BIRMINGHAM.

use of a lubricant materially affects the success of a drawing operation, facilitating the flow of the metal and enabling the action to be carried on with the minimum of wrinkling and elongation.

Principal Types of Drawing Presses.—The methods of producing the double action are by cams, by toggles, and hydraulically, although presses working on the latter principle are relatively few in number. The essential difference between cam and toggle operation lies in the manner in which the holding pressure is taken ; in the one the crankshaft has to carry the forming and the holding load, in the other the latter load is received by the frame. Therefore for heavy duty the toggle press has to be selected. Furthermore, the wear on the cams has to be considered when heavy pressures are consistently required. Many models are consequently built in each type.

Cutting-and-drawing Presses.—The smaller sizes, up to about 5 inches depth of draw capacity, are freely employed for blanking and drawing, using hand or roll feeds. The combined cutting punch and pressure plate descends with the outer slide and shears the blank, which is then drawn through the die by the punch (Fig. 29). One of the smallest presses for this class of working has the following specification :

Stroke, outer slide	$\frac{3}{4}$ inch
Stroke, punch	$1\frac{1}{2}$ inches
Strokes per minute, usual	250
Feed of strip, maximum	$\frac{7}{8}$ inch
Width of strip, maximum	2 inches
Bed to outer slide, adjustment up, stroke up	6 inches
Bed to inner slide, adjustment up, stroke up	8 inches
Adjustment to outer slide	$\frac{1}{2}$ inch
Adjustment to inner slide	1 inch
Width between sides of frame	$7\frac{1}{2}$ inches
Depth of throat	$3\frac{1}{2}$ inches
Bed : Right to left	13 inches
Front to back	7 inches
Hole through bed	3 inches
Power required	$\frac{1}{2}$ h.p.
Overall height	65 inches
Net weight	$5\frac{1}{2}$ cwt.

The series of presses made by Taylor & Challen, acting on the same principle, have drawing depths of $\frac{3}{4}$ inch, $1\frac{5}{8}$ inches, $2\frac{3}{4}$ inches, 4 inches, and 5 inches respectively.

The movement of the cams is transmitted to the outer slide by a pair of loops, fitted with rollers in the top and bottom ends, the rollers running in oil-baths. The equivalent of this construction in some presses is to carry up four rods and attach a cross-head at the top for the rollers there. The rods may be prolonged upwards to slide through guide brackets. In all the heavier kinds of presses, however, the practice is generally to have rollers only at the top of the slide and fit a spring balance arrangement consisting of four springs anchored to the slide at front and rear, and to brackets on top of the cross-beam (Figs. 30 and 31).

Light presses are direct driven by the flywheel on the crankshaft,

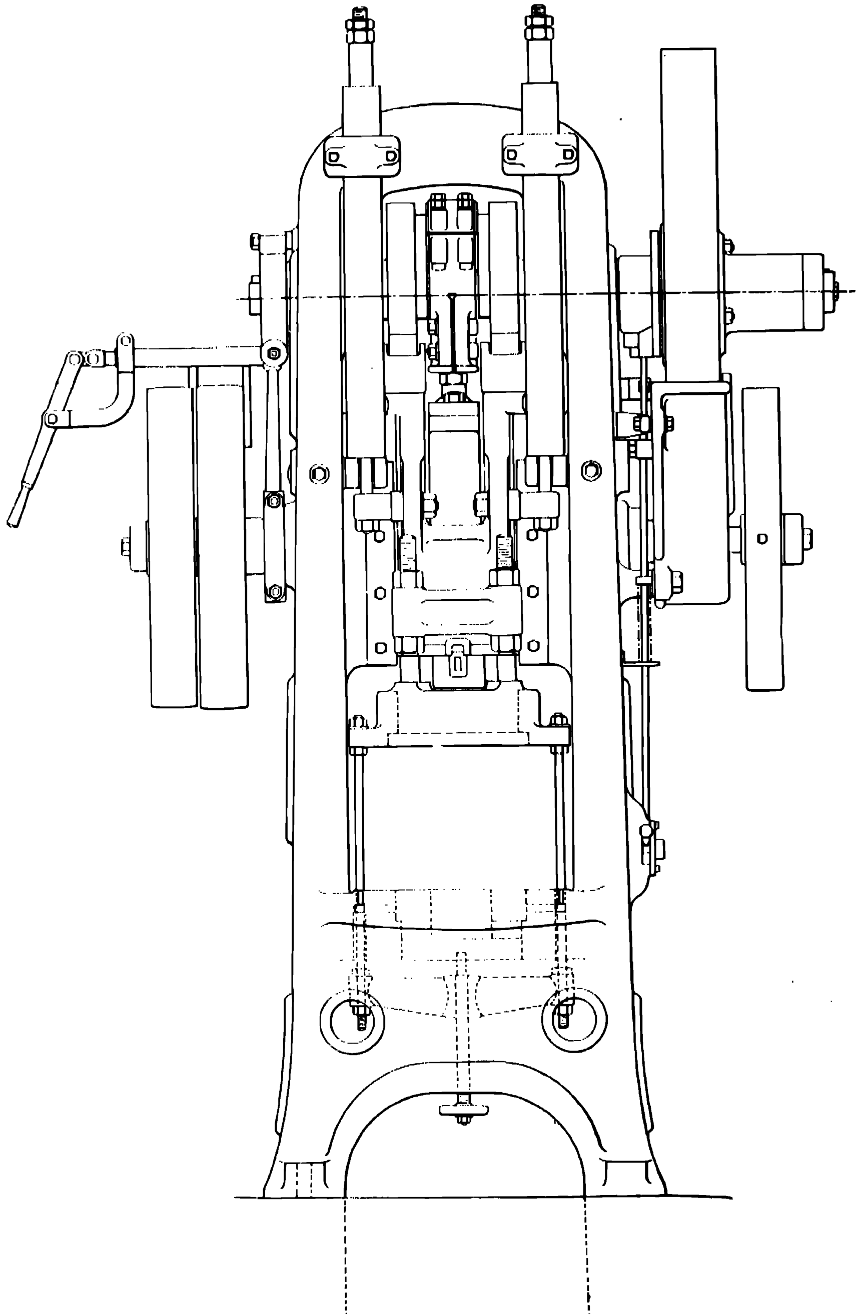


Fig. 30.—Double-action cam-operated drawing press. (Hordern, Mason & Edwards, Ltd., Birmingham.)

heavier styles by single gearing. Double-reduction gears are provided in the larger models in order to give a comparatively slow motion to the punch, and less shock to the metal undergoing treatment. A few of the particulars of a Taylor & Challen machine of this description are appended :

Deepest draw	5 inches
Stroke : Outer slide	$5\frac{1}{4}$ inches
Punch	10 inches
Largest blank admitted	14 inches diameter
Largest punch admitted	10 inches diameter
Strokes per minute, usual	16
Bed to pressure plate, adjustment up, stroke up	12 inches
Bed to punch holder, adjustment up, stroke up	16 inches
Adjustment to pressure plate	2 inches
Adjustment to punch holder	4 inches
Motor	8 h.p. at 985 r.p.m.

This press will draw 10 inches diameter by $2\frac{1}{2}$ inches deep from a blank 14 inches diameter, or $5\frac{1}{2}$ inches diameter by 5 inches deep from a blank 12 inches diameter.

The disposition of a positive bottom extractor is seen in Fig. 30, worked from the rods screwed to the blank-holder. The alternative of a spring extractor is furnished in some of the light machines.

Fig. 31.—A similar press to that shown by Fig. 30.

Toggle Presses.—In these the crankshaft has only to take the drawing pressure, but not the blank-holding pressure owing to the connection of the toggle links to the frame, against which they thrust. The system is adopted up to very high powers, of 400 tons or more drawing pressure. Pressure is maintained during 90° angular movement of the crankshaft. The main variations in the constructional features may now be considered.

Frames.—The differences in regard to these depend upon the height necessary, the width, and whether a single- or double-crank drive is used. A small press will measure 2 feet between the sides,

one of the biggest measuring 18 feet and taking about 125 h.p. to drive. A single casting is practicable for moderate sizes, but the built-up design is adopted for some of these, as well as for large machines. The bed, standards, and top girder are keyed and bolted together, shrink tie-rods being fitted to take the stresses. A dropped bedplate will be provided on an otherwise standard press in order to give increased height for deep-drawing tools. As an example, the regular (maximum) height from pressure plate to bed, $43\frac{1}{2}$ inches, will be increased to 54 inches by fitting a low-level bed.

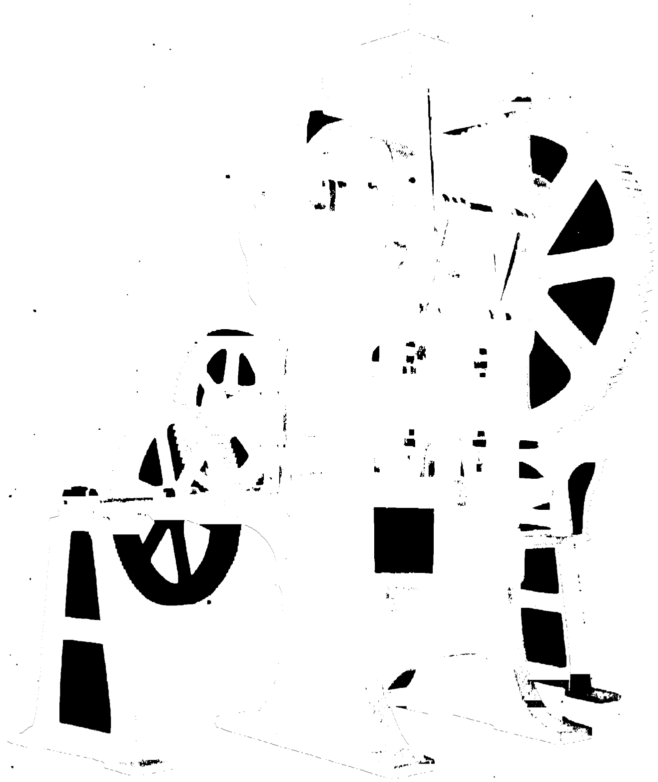


Fig. 32.—Toggle drawing press having balanced slide. (Lee & Crabtree, Ltd.)

Balancing.—The mass of the slide is counter-balanced with four springs in medium-sized presses and by weights in other cases, the latter being located at the top of the frame (Fig. 32). The alternative is to bolt weights to the arms of the gears on each end of the crankshaft. Buffers are also fitted to the toggle arms in many presses.

Slide Adjustment.—The adjustment of the blank-holder by ordinary nuts on the bolts gives place to hand-wheel and worm-gear mechanism in big presses, while a motor actuates the punch adjustment.

Pneumatic Blank-holder.—This is a special fitting found on the Schuler presses and is intended to enable the pressure to be ascertained with accuracy, and maintained so as to give the best results. A ring-shaped holder has a spherical bearing surface, and the air pressure within is regulated until it is found that a blank is drawn without wrinkling. Once the pressure has been determined its absolute value is stamped on the tool, and no further experiments are necessary for the next occasion. As the piston is free to float it adapts itself easily to the unevenness of the sheet, or to any irregularity in the press action caused by wear. The fitting time for tools is shortened,

because adjustment of the blank-holder pressure is effected by altering the air clamping.

Methods of Driving.—The mode of driving a drawing press depends on its type and dimensions, the direct drive being suitable only for the smallest machines. Thence the transition goes through single gearing, double gearing, and treble gearing to the most powerful types, which have twin drive for the crankshafts, the gears at each end preventing any risk of twisting. In order to leave the floor space clear some makers prefer to put the motor on a bracket at the side or top of the framing.

Clutches.—The sliding or rolling key clutch which is applied to blanking presses has a more limited use as regards drawing presses. Some of the latter, in the smaller sizes, employ these clutches, but for proper control of long strokes a friction clutch becomes essential. An automatic key clutch is fitted to Taylor & Challen drawing presses of the cam style, the shape of the key being similar to that of the clutch illustrated on p. 3. On some of the toggle presses a gripper friction clutch is used, comprising pairs of pivoted pincer-like grippers that seize a rim on a clutch disk attached to the first-motion pinion. A driver, carrying the grippers, rotates with the driving shaft, and a sliding cone also revolving with the shaft affords the means of operating the grippers. The starting lever has to be pulled off a projection on a vertical rod connected to the crankshaft, thus enabling the sliding cone to be moved, causing its taper surfaces to expand the gripper ends and start the drive. As the crankshaft revolves the vertical rod descends far enough to allow the projection on it to come under the starting lever, and when the slide has nearly reached the top point of its stroke again this rod rises quickly, carrying the starting lever with it and throwing out the clutch, a brake-band being tightened around the clutch disk at the same moment. An emergency lever is also placed in a convenient position, enabling the press to be stopped instantaneously.

A similar mode of control is utilised for this firm's multiple-plate friction clutch installed on all the more powerful presses. This has a series of inside and outside clutch plates running in an oil-bath and engaged by the action of toggle levers controlled by a sliding ring. The friction clutch provides a smooth and shockless engagement, and perfect control at any part of the stroke.

The construction of the multiple-disk clutch fitted to Rhodes' presses is seen in Fig. 33. It is built into the flywheel, which has grooves for vee-ropes, and rotates on roller bearings.

Capacities of Toggle Presses.—A comparison of the capacities and principal dimensions of small and large presses by Taylor & Challen may now be given. In the first case the drive is by a double gearing on to the crankshaft; in the other, treble gears are employed with twin gears on the crankshaft.

SMALL TOGGLE PRESS

Deepest draw	7½ inches
Largest blank admitted	18 inches diameter
Largest punch admitted	12 inches diameter
Stroke: Outer slide	7½ inches
Punch	15 inches
Strokes per minute, usual	10
Width between sides of frame	24 inches
Bed to pressure plate, adjustment up, stroke up	21 inches
Bed to punch holder, adjustment up, stroke up	28½ inches
Adjustment to pressure plate	3¼ inches
Adjustment to punch holder	2¾ inches
Bed, front to back	26 inches
Power required	5 h.p.

LARGE TOGGLE PRESS

Deepest draw	18 inches
Largest blank admitted	54 inches diameter
Largest punch admitted	35 inches diameter
Stroke: Outer slide	18½ inches
Punch	36 inches
Strokes per minute, usual	3¼
Width between sides of frame	56 inches
Bed to pressure plate, adjustment up, stroke up	43½ inches
Bed to punch holder, adjustment up, stroke up	52¾ inches
Adjustment to pressure plate	4 inches
Adjustment to punch holder	6 inches
Bed, front to back	68 inches
Power required	75 h.p.
Net weight	980 cwt.

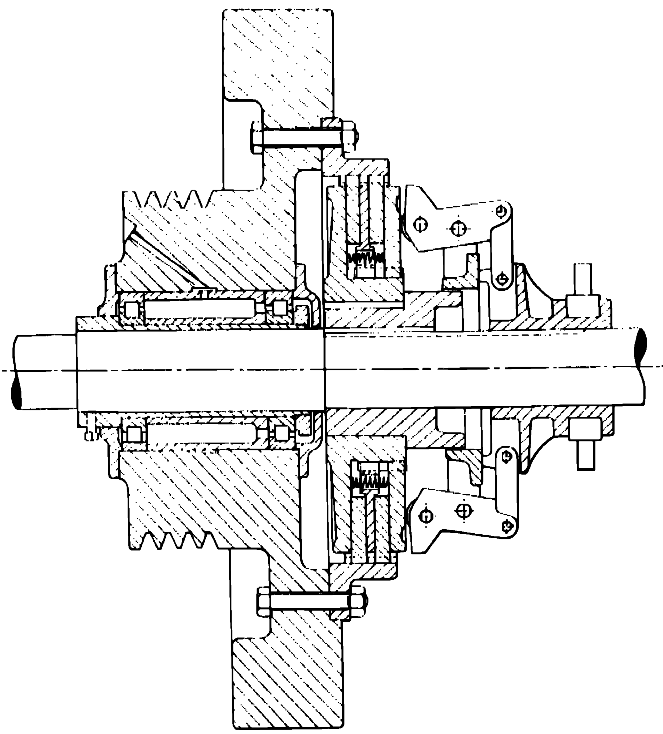


Fig. 33.—Rhodes' multiple-disk clutch.

One of the largest Bliss presses has an area of bed of 65 × 218 inches, takes 125 h.p. to drive, and 20 h.p. for the adjustment of the inner slide. The crankshaft is 16 inches diameter at the journals, and 17 inches at the crankpins. The gears at each end of the crankshaft are 12 feet diameter. The framing of this machine is built-up, with keyed joints and four shrink bolts.

Rising-table Toggle Press.—A different method of working is to be noticed in a press which has the usual crankshaft action for the punch-holder, but carries a fixed blank-holder, adjusted by threaded bolts to the position required. The holding pressure is supplied by the table, which is raised by toggle levers actuated from rods reaching from the crankshaft ends down the outside of the frame. This arrangement gives abnormal tool space, and end play in the toggle mechanism is absorbed automatically by the weight of the table and die. An ejector placed under the table extracts the pressing as the table descends. The punch has a stroke of $14\frac{3}{4}$ inches, but if the blank-holder is removed to convert the press to single action the combined movement of table and slide affords the exceptionally long stroke of $23\frac{3}{4}$ inches.

It may be mentioned that the inverted principle has long been employed for certain kinds of drawing, notably that of hollow ware for which a long stroke but low holding pressure is required. The presses made for this duty carry a stationary blank-holder, and the table is raised by cams, while the punch descends. Free access is given to the table by the disposition of the driving gears beneath the floor.

Single-action Drawing Presses.—For those classes of work not needing a blank-holder, a good many kinds of single-action presses, both long and short stroke, are supplied, fed either by hand or by pusher, dial, or some other mechanical system. The double-sided frame is mostly used, although some of the lighter work is drawn on open-front machines. The points which differentiate many of the drawing presses are extra long stroke, necessary for much drawing and extending, and great power so as to sustain the load which occurs for a good portion of the stroke. An exception to the usual cycle of stopping at the top of the stroke occurs in cases where a dwell is required at the bottom of the movement, the brake arrangement being modified accordingly. This difference is necessary when moulding plastic substances, vulcanite, pulp, and various other compositions. Considerable height is essential for drawing long shapes, but a hinged punch holder sometimes enables a short stroke to be employed for certain operations on long articles. A pressure of 2,000 tons is exerted in the heaviest presses.

Typical Presses.—One of the smallest double-sided models gives a pressure of 20 tons at the bottom of the stroke and requires 1 h.p. to drive it. The stroke is 6 inches with an adjustment of 2 inches, ample height being provided for deep drawing, the distance from the bed to the punch-holder being $20\frac{1}{2}$ inches. In a 40-ton press the stroke is variable from

8 to 10 inches. Data for a double-geared machine developing 100 tons pressure are :

Stroke	16 inches
Strokes per minute, usual	8½
Adjustment to slide	2 inches
Width between sides of frame	24 inches
Motor	10 h.p.

The twin-gear method of rotating the crankshaft is employed on many of the heavy presses, and the tie-bar form of building up is frequently adopted. A special way of carrying the crankshaft is to be seen in a Taylor & Challen 2,000-ton press, the shaft having turned webs adjacent to the connecting rod, these being supported by large cylindrical bearings cast with the frame and fitted with gunmetal liners. The shaft is thus enabled to transmit the heaviest pressures without any tendency to spring. The frame and chief working parts are of steel. The following particulars of this big machine may be noted :

Stroke	24 inches
Adjustment to slide	⅜ inch
Strokes per minute, usual	3
Width between sides of frame	72 inches
Bed to slide, adjustment up, stroke half-way down	49¼ inches
Bed, front to back	72 inches
Hole through bed	37 inches
Diameter of crankshaft journals	18 inches
Diameter of crankpin	25½ inches
Overall height	275 inches
Motor	100 h.p. at 530 r.p.m.
Net weight	116 tons

Horizontal Presses.—For some specialised purposes drawing or extending presses lie horizontally, one of the principal applications being for cartridge cases. A direct or a geared drive is employed, and the cases are fed down an inclined chute, the punch taking each and extending them to the correct length, after which the extractor gear ejects the case. The speed of working is about one per second, and lengths of stroke range from about 5 to 9 inches in different machines.

Hydraulic Presses.—These are made to large dimensions on the double-action principle. One system is that of placing the drawing die on the cross-head, and running the blank-holder and the drawing slide on two pistons working inside each other in a common cylinder. Another is to have the blank-holder and the drawing slide running downwards, as in the toggle presses, the drawing slide being moved by means of a ram in the middle and the blank-holder slide by two rams in the smaller sizes, and four in larger ones. An example of this type gives a drawing pressure of 400 tons, and blank-holder pressure of 320 tons. The relative pressures can be controlled separately. The equipment consists of a low-pressure and a high-pressure accumulator, a high-pressure pump, and high-pressure

compressor, and the necessary regulators and controls. The accumulator supply enables the speed to be slow or fast according to the demands of the object, or the drawing properties of the metal.

A modified type of press, which is comparatively low in cost, deals with large curved parts, such as panels. The scheme consists in stretching the sheet over a form (which may be of wood) mounted on a table, and setting down grippers at each side, the grippers remaining stationary while the form rises with the table by hydraulic ram action. A counter-pressure device on an overhead cross-head may be applied to form impressions opposite from the drawing motion.

Screw Presses.—In contrast to the high-speed friction screw presses which deliver a sharp blow, a limited number of drawing presses are used giving a long, slow, drawing stroke by means of a screw; both open-fronted and double-sided types being so built. A maximum pressure of about 170 tons is attained in the largest sizes, with a stroke up to about 2 feet. The drive is by open and crossed belts and a friction clutch, with automatic reverse at a higher speed. When a separate motor is employed the load on it is reduced by arranging a flywheel drive.

Duplex horizontal screw presses carry tilting punches at each end of the screw, and the dies go in cross-heads tied by powerful bolts. A screw of 7-inch diameter gives a rate of travel of 75 inches per minute and a stroke of 30 or 45 inches. Open-and-crossed belts on the pulleys transmitting to the gears effect automatic reverse.

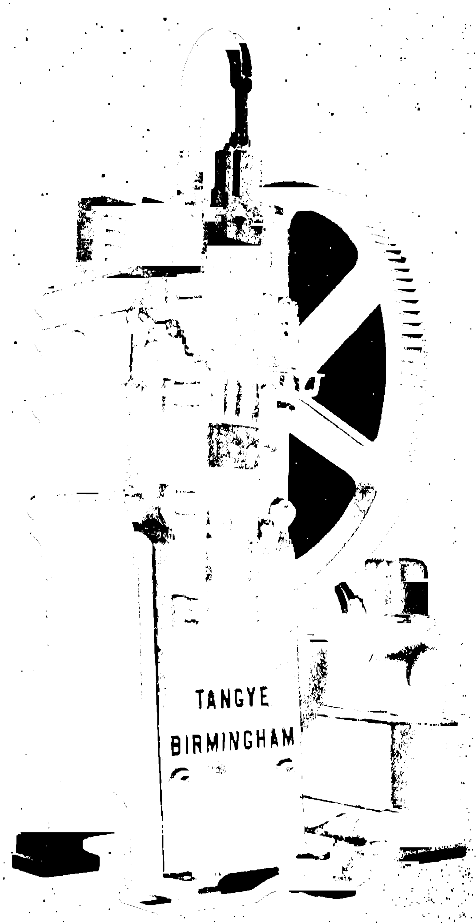


Fig. 34. Long-stroke twin-rack drawing press for shell cases.

Rack Presses.—Another way of obtaining a long draw is through the medium of a rack, machines being constructed thus chiefly for drawing shell cases. The Tangye press has two racks, and while one is descending and drawing the case the other is lifting ready for the next draw. A Ward-Leonard drive is installed (Fig. 34), and the series of standard sizes rate as follows :

Maximum stroke	inches	24	30	33	48	60	84
Maximum diameter drawn	,,	3	4	4	6	6	8
Maximum length drawn	,,	10½	14	16	21	27	39
Speed of drawing	feet per min.	10–30	10–30	10–30	4–24	4–20	4–16

Cold Extruding.—An interesting process of drawing tubular shapes from soft metal is by extrusion, suitable for making shells, cases, and tubes in tin, lead, and aluminium. Rapidly applied pressure causes the metal to flow out of the die (Fig. 35) up around the punch, from which it is next stripped. The heat developed by the blow assists the flow, the length of the piece produced from a given punch depending on the thickness of the blank. In prolonging tubes from the more delicate metals, such as lead and tin, the work must be carried on at a lower speed than with aluminium, consequently the presses for the last named may be operated at about eighty strokes per minute, double that practicable for the other metals. A particular make of horizontal press is arranged to be fully automatic, the blanks being fed to the die automatically, and finally removed by a conveyor band. Vertical presses are usually fed by hand or from a magazine, in the former case the punch-holder swinging in and out automatically, the work being stripped from it by hand, a blank being then placed in the die. To render this act safe, duplex starting levers are fitted, so that the machine cannot be run unless both hands are on the levers. The output on a fully automatic type will reach 4,000 pieces per hour.

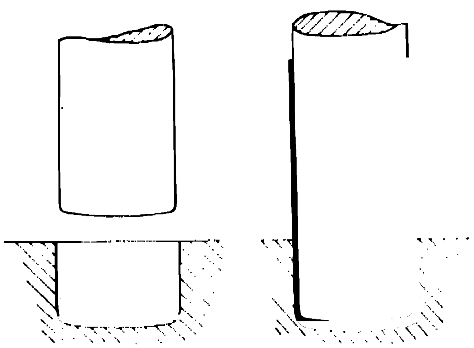


Fig. 35.—Cold-extruding method for soft metals.

Compressing Methods.—An interesting phase of press work is that of compression, a kind of drawing or reducing in which the shell is necked, or formed into globular shape by dies, either at one operation, or in two or three dies. Materials are also compressed by punches into convenient form for use, or to act as charges of definite size to go in sheet-metal containers. In one instance, fabric is squeezed into a small cylindrical piece by the punch descending on the material as it lies in the die, an ejector then pushing it out, a dial feed being utilised to carry the dies around. In another case, a hopper feeds powdered material, the attendant depositing a measured charge in the hopper, and this moves forwards, loading the die. As the hopper returns the punch comes down and compresses the powder into a pellet, after which it is ejected and swept away on the next stroke of the hopper. A safety shield is hung in such a manner that if the hand attempts to follow the hopper the shield moves and stops the press.

Feeding Methods.—Emplacement of a blank on the die must be effected by hand in a great many examples, but whenever possible this

practice is to be avoided. The roll feeds in the cutting-and-drawing presses supply a means of automatic working, but when units have to be fed, the choice may be either that of a sliding or swinging table, feed fingers, or a turntable. The sliding-table device enables the operator to place the blank upon it, and it is then taken forward over the die, removal after drawing being performed by an air blast. A device for locating large blanks is attached to the blank-holder, and consists of guide strips extending out from it. The blank, being laid on these, can be pushed along by hand through the assistance of a slide piece, thus becoming accurately located in relation to the die, ready for pressing. This arrangement allows blanks to be fed without waiting for the ejection of the previously drawn article.

A combination of a safety guard with automatic feed fingers supplies the method of passing cups to the die for a second drawing. The attendant places a cup on a smooth plate, and as the ram begins to descend the fingers seize the cup, and lay it in position on the die, at the same time pushing off the previous drawing. At the return stroke the fingers open and go back for another cup. The netting guard permits a view of what goes on, but if touched will stop the press.

Fig. 36. 100-ton drawing press fitted with turntable.

Turntable Feed. This serves for a great many redrawing operations, the speed being determined by the ability of the operator at the loading station, although certain objects can be supplied *en masse* on to a smooth table from which they are transferred to the turntable, the rate of feed being thus much increased. For some necking operations the table will carry a circle of punches on to which the drawn blanks are placed, whence they come under a die which performs the necking. Successive operations occur when it is not desirable or possible to change the form by one die only, an example of this being seen on a double-crank press, the wide

slide of which holds the three tools, the turntable bringing the cups successively under them. Springs or positive extractors are arranged in conjunction with turntables. Fig. 36 shows a press having a 12-hole turntable.

Die-cushions.—The counter-pressure applied by a cushion in a combination die enables single-acting presses to be used for a wide range of blanking and drawing operations. For comparatively shallow draws a rubber buffer is suitable, but springs are provided in many instances as an alternative, regulation of the degree of pressure in either type being made by means of nuts. Two designs of pneumatic cushions are available for performing the same function, one with moving cylinder and the other with moving piston. The differences are seen in Figs. 37 and 38, from which it will be clear that the pressure of the apparatus is transmitted by pins to a pressure plate, and thence by other pins to the blank-holder. The combined punch and drawing ring descends and cuts the blank, then presses it against the blank-holder, which retires as the drawing action takes place. The objection to the spring device is that it causes increase in pressure during the descent, but this is not the case with the pneumatic cylinder. Multi-cylinder outfits are made for large work. Installing a multi-cylinder set in the table of a double-action press converts it to triple action, as after the main draw has been performed, a counter-draw can be made. Pneumatic cushions are sometimes mounted in the press slide to act as an additional blank-holder.

Marquette Die-cushions.—These are built in many types for different powers and methods of application, and a résumé may be offered.

The simplest design is supplied for light high-speed operations on covers and bottoms, caps, rings, etc., in thin metal, and the unit is self-contained, requiring no tank, as the air is taken direct from the pipe-line and goes through a check valve with a gauge which regulates and records the pressure desired. A record can thus be kept so as to be able to set the cushion quickly for any job. A handle is turned until the gauge shows the correct pressure. The constant uniformity of pressure during the draw saves losses from wrinkling or tearing. The pressure is automatically maintained to that set, independently of any variation in the line pressure. Installation is simple, as only two screws are required to attach the cylinder under the bed, and a quick-lock coupling to the hose. The four sizes of this outfit rate thus :

Diameter of piston	inches	4	6	8	10
Maximum height	inches	9	10	10	11
Maximum draw, standard	inches	1	1	1	1
Largest diameter light-gauge blank	inches	4	6	8	10
Blank-holding pressure, 80 lb. line	tons	½	1½	2	3½
Weight of cushion and piston	about lb.	20	30	35	40

Another simple style (Fig. 37) is devised so that it can be substituted for a rubber bumper or spring outfit, without the necessity of doing any

machining work, because a central stud is fitted to the cylinder and holds it in place similarly to either of the equipments mentioned. The same system of pressure control and direct-line supply is adopted as with the other style.

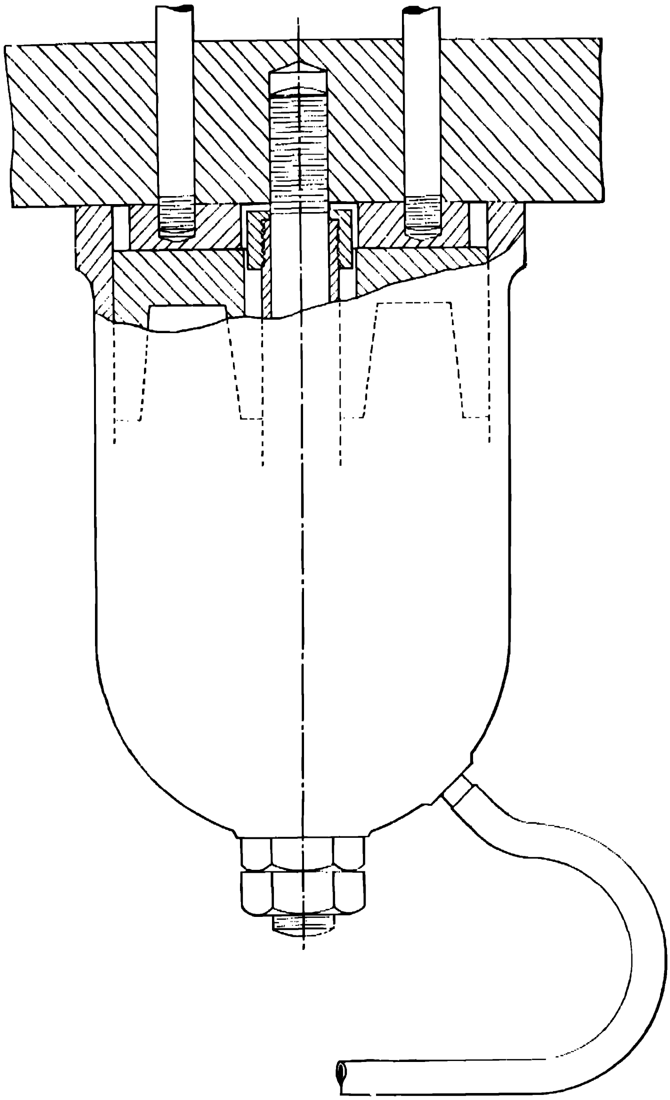


Fig. 37.—Light-weight high-speed Marquette die-cushion.

Fixed-piston and Moving-piston Cushions.—A range of cushions is made which are run in connection with a surge tank, one for each unit, this being essential in order to give a uniform pressure for the full stroke, the air in each equipment being displaced into its tank to obtain various pressures for different jobs. In the two variations of principle of opera-

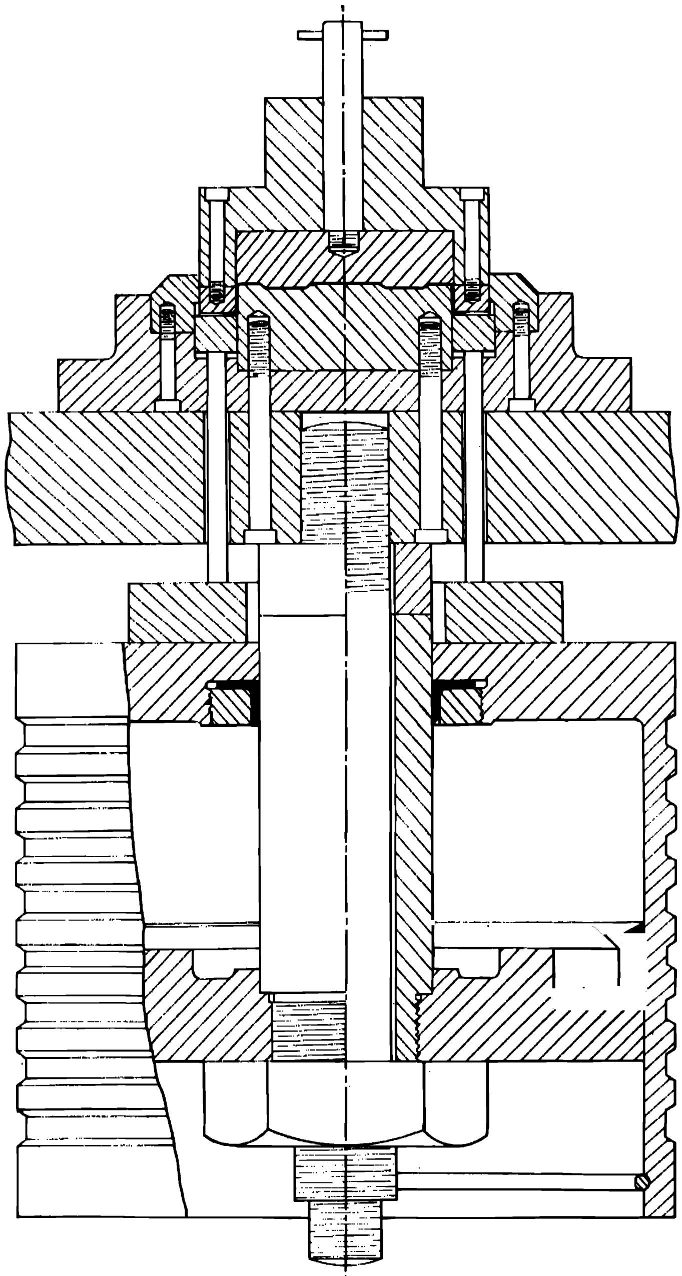


Fig. 38.—Marquette pneumatic die-cushion of moving-cylinder type.

tion, one has a fixed piston and moving cylinder (Fig. 38), the other the opposite conditions (Fig. 39). In the first case the piston is strung on a hollow shaft secured under the bed by a bolt, in the other case the cylinder is supported by a plate and bolts, or other means. The fixed-piston model is readily substituted for a rubber or spring set.

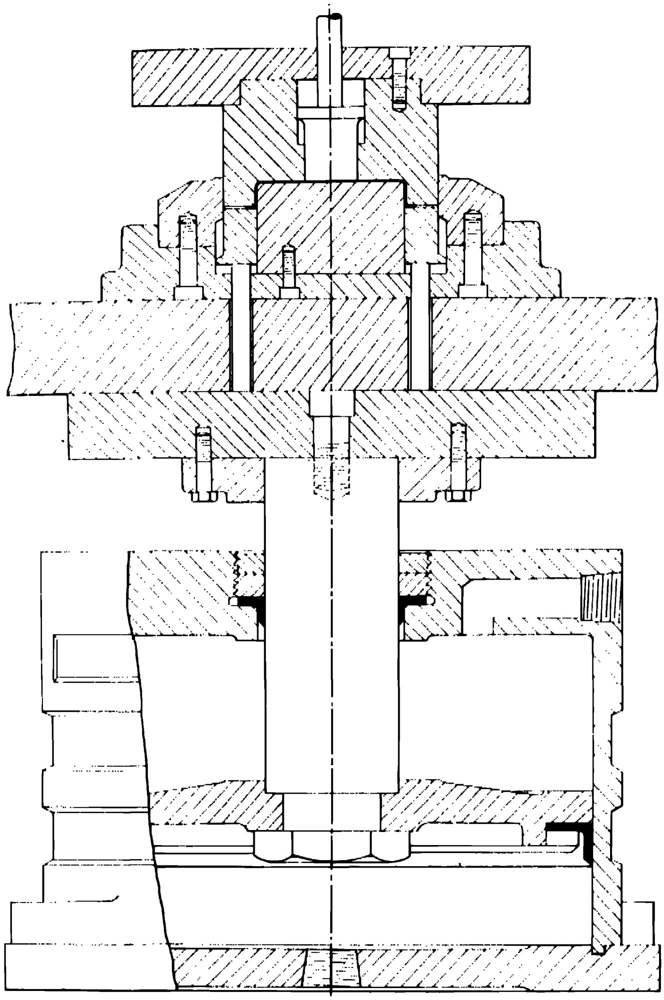


Fig. 39.—Moving-piston type of Marquette die-cushion.

Single-piston and Double-piston Cushions.—The object of making double-piston cushions (Fig. 40) is to double the power, so that they can be placed under a press which is not large enough to accommodate a single-piston cushion of sufficient power for the purpose. Duplicated cylinders receive the pistons, the mode of attaching the piston rod to the bolster plate being by a thread. The sizes of the cushions are designated by symbols giving the bore of cylinder plus the stroke, and twenty-two stand-

ard sizes are furnished in both single- and double-piston types. The smallest single has piston diameter and stroke 4—2 inches and gives 0·6 ton pressure from 100 lb. supply, while the largest is rated 12—6, and affords 5·6 tons pressure. The pressures in the minimum and maxi-

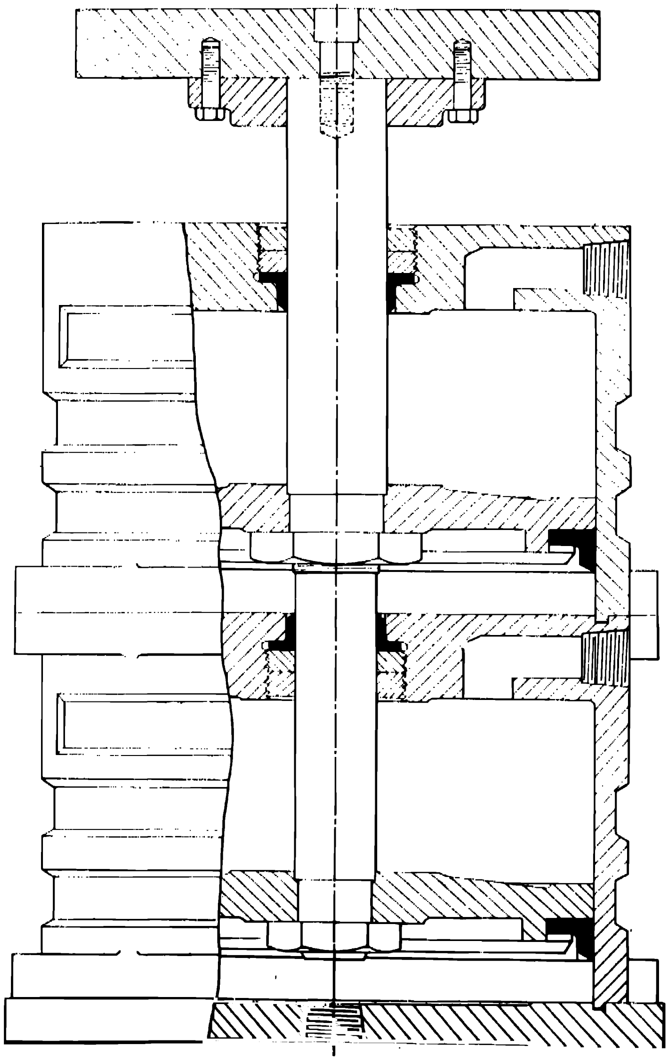


Fig. 40.—Double-piston die-cushion. (Marquette.)

mum sizes of double-piston cushions of similar rating to those in the foregoing sentence are respectively 1·2 tons and 11·2 tons.

Triple-piston Cushions.—To obtain still greater power, for heavy presses, three pistons run in superimposed cylinders, and a pressure of 186 tons results from this arrangement in the largest set, of 40 inches bore.

Multiple Mountings.—Two, four, six, or more cushions are employed in the larger presses, there being as many as sixteen in big double-crank machines, suspended from rods and a bottom plate. Spacer blocks inserted between the plate and the bed increase the rigidity.

Telescoping-cylinder Cushions.—A compact style is obtained by a double-cylinder construction in which the inside cylinder forms the piston for the outside cylinder, and there is a separate piston for the inside cylinder, consequently little space is occupied for the length of draw. This arrangement (Fig. 41) provides extra long guides for the outside cylinder, and prevents deflection of the movement. The combined pressure capacity of the outer and inner cylinders with their respective pistons is equal to that of double-decked cylinders of the same piston area.

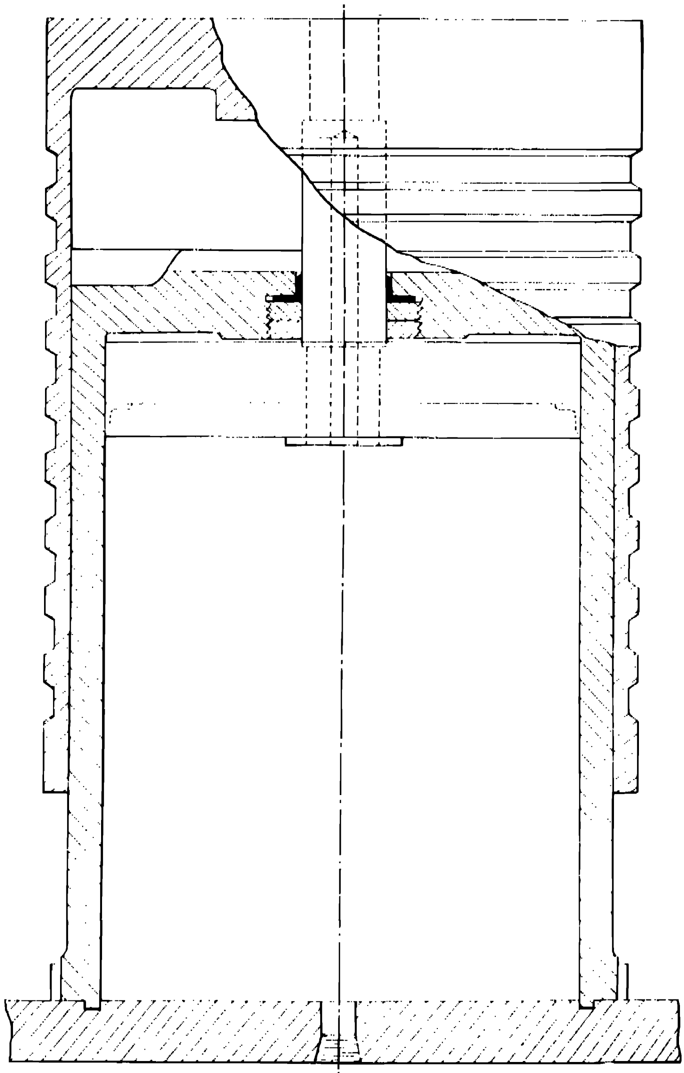


Fig. 41.—Telescoping-cylinder design of Marquette die-cushion.

Cushion Beds.—A development from the separate blank-holder idea is that of building cushions integrally with the press bed (Fig. 42), a scheme conferring many advantages, as thus: deep pit foundations, otherwise necessary to accommodate cushions underneath the bed, are not required, and the cost of a foundation, should it be found needful to move the press, is much reduced. Pressure tanks are not wanted, as the bed has cored chambers around the cylinders acting as a reservoir for the displaced compressed air which flows from the cylinder into the space surrounding it. Most of the piping and joints are eliminated. Greater rigidity

is secured to the equipment. The number of cylinders may be varied; two can operate two pressure plates working together with uniform pressure,

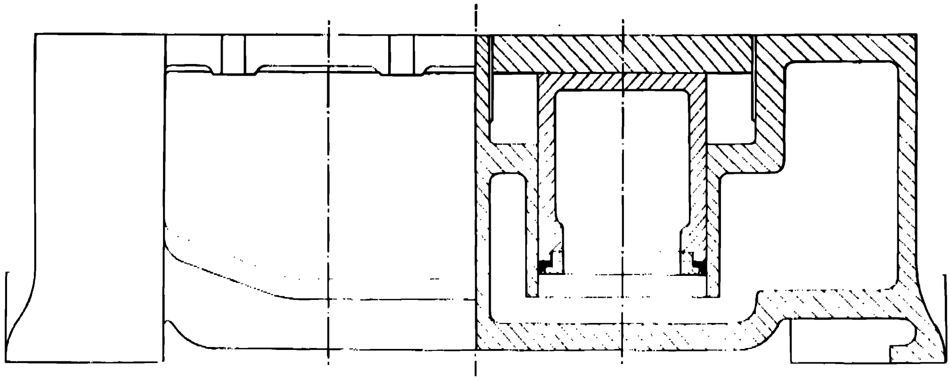


Fig. 42.—Marquette pneumatic cushion bed.

or independently with either uniform or varied pressure. Or six cylinders will actuate three pressure plates, two cylinders to each plate, the plates working uniformly or independently, and with either uniform or three varied pressures.

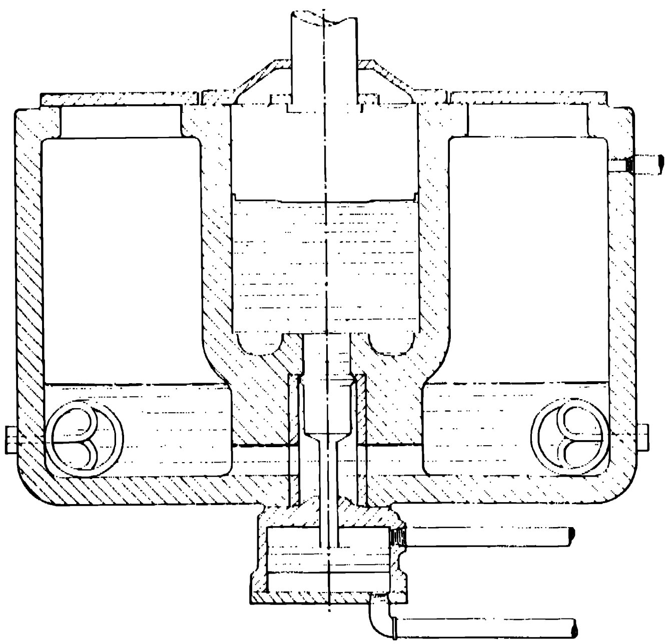


Fig. 43. Hydro-pneumatic die-cushion. (Marquette.)

Hydro-pneumatic Cushions.—Pressures ranging from five to ten times those given by the pneumatic cushions are delivered by an oil cylinder fed from a tank into which the compressed-air supply is led. A relief valve controls the drawing pressure. Two-step or varied pressures can be arranged, so as to impart a heavy blank-holding grip at first, then a lighter one to complete the draw. The cushions may be built into the press beds to make a very compact system, and the surge reservoirs are cast around the cylinder (Fig. 43). In an example of a very large press the cushions are divided into five independent units: five double-action dies may be worked independently at the same time, or all the cylinders can be synchronised to act together.

Rotary Valve Control.—For the most effective control and timing of the action of cushions and knock-out pads or lifting cylinders, a rotary valve control is utilised, driven by a chain from the press crankshaft and turning cam drums, which revolve once for each stroke of the press. Great accuracy of timing is obtained by adjusting the cams in T-slots, and they operate poppet valves which give quick action.

Hydro-pneumatic Locking Devices.—An application of the hydro-pneumatic action is that to locking devices for both pneumatic and hydro-pneumatic die-cushions. The purpose is to hold down the pressure pads on single-acting presses, also on double-acting presses until the slide has receded and left the die, thus preventing the pressure pad from striking the bottom of the stamping before the blank-holding pressure has been released, and spoiling the work. They are also used for delayed stripping in both slide and bed, and for raising the piece in the die after the up stroke so that removal may be done by hand. When used with pneumatic cushions the locking device consists of hydraulic cylinders connected to the pressure pads, and suspended under each pneumatic cylinder. The sequence of action is, that as the drawing slide comes down and strikes the pressure pad, the piston of the locking device is pushed down with it, causing the oil to move from the lower side of the piston to the upper side through ball check valves and a valve port. When the pressure pad and the locking-device piston are at the bottom stroke the air-cylinder piston which actuates the locking device moves in to close the return valve to prevent any oil from going from the upper side of the piston back to the lower side, and this is what locks the pressure pad down. The air cylinder is arranged to actually push the locking-device piston and the pressure pad down a little farther, in order to overcome any tendency of the pressure pad to creep back a little and possibly distort a stamping, due to air trapped in the oil or in the packing.

Two units of the rotary control valve provide the proper timing of the dwell, and the up-and-down movements of the pressure pad. The cams are set to exhaust the air on one side of the air cylinder at the correct moment, usually at about mid-stroke up, and admit air on the other side of the piston to open the relief valve which permits the oil to return, breaking the lock, and allowing the pressure pad to return to its top position. The Marquette equipments are made by the E. W. Bliss Company.

The Simplex Drawing Device.—A purely mechanical equipment which enables a single-action press to do the work of a double-action cam or toggle press is shown in Fig. 44. This is made by Joseph Rhodes & Sons, Ltd., and is located under the bed of the machine. The same general principle is followed in different sizes, those for the heavier duties necessarily having certain constructional modifications. The blank-holding pressure is automatically provided by the mechanism, being self-forming and self-compensating, according to the thickness of

the metal being drawn, there being no need to sort out varying batches of blanks as regards thickness. In mild steel two-thirds of the diameter can be drawn at one stroke without trouble, an example of this being a stainless steel stew-pan which is drawn in 18 s.w.g. $10\frac{1}{2}$ inches diameter by 8 inches deep, and as the pressure is automatically regulated, difficulties with tearing or wrinkling are eliminated. Cutting and drawing may be done at the same operation if necessary.

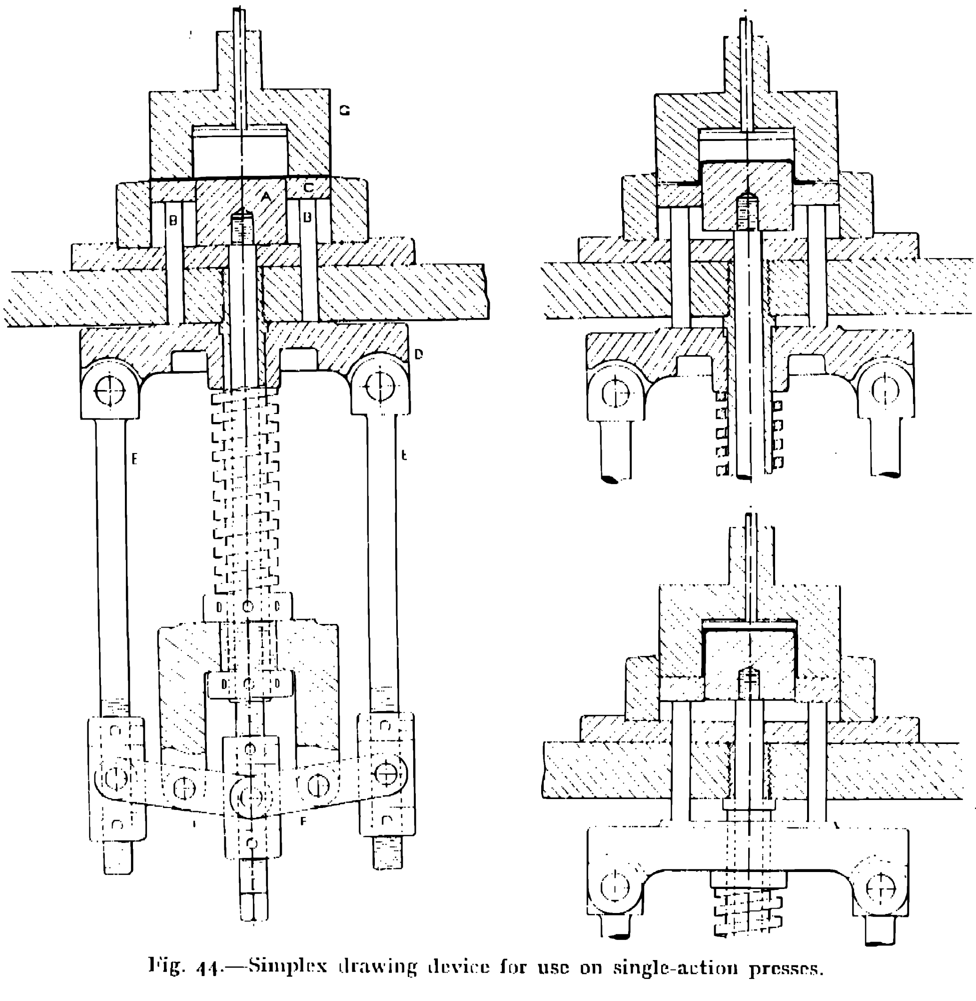


Fig. 44.—Simplex drawing device for use on single-action presses.

In its simplest form the arrangement consists of a tube screwed to the bed, the attachment being suspended therefrom. A rod passes through the tube, to be screwed to the forming block A of the bottom die. When working, the pressure pins B, B are forced down by the ring C, and they thrust down the platform D, which causes levers E to move the toggles F, and lift the centre rod. As a result, the block A rises into the top die at a rate proportional with that of the downward movement. The blank,

when subjected to this action, sets up resistance to the upward motion of the forming block, by which the requisite drawing pressure is obtained. The spring seen is not used for the drawing operation, but serves to bring the levers back to the normal position, and eject the stamping. As the bottom block travels upwards in accordance with the downward move-

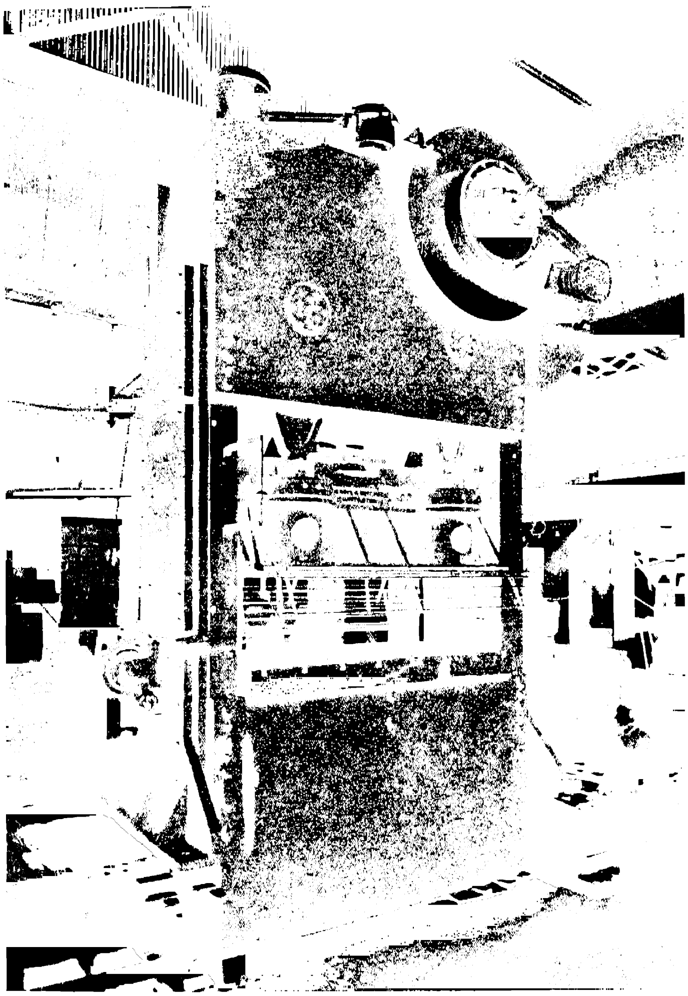


Fig. 45.—Showing the deep frame required below the bed of a large press. (Wilkins & Mitchell, Darlaston.)

ment of the top die, a shorter stroke is therefore necessary than by any other system. For example, a stamping 4 inches deep only requires a stroke of $6\frac{1}{2}$ inches (allowing $\frac{1}{2}$ inch for clearance) as against $8\frac{1}{2}$ inches when using a double-action press. The heavier designs have toothed levers at the bottom, instead of the pivoted levers, the teeth on their radial faces meshing with rack teeth on each side of the central rod.

Press Controls.—The hand lever or pedal control which is usual in a

large number of instances is varied in order to provide a greater measure of safety provision, a two-handed control obviating the risk of the hand being in danger, since both hands must operate the starting levers before the press will run. On large machines mechanical means are superseded by pneumatic or electric controls, and in the latter, by means of a push button, the slide can be stopped and started again, the machine being instantaneously stopped if the button is released.

Press Foundations.—The form of foundation used depends in the larger presses on the style of bed, what fittings go underneath it, and whether the driving details or an air compressor lie at the side. Many designs need only a bracket bolted at the side and resting upon the floor, for this purpose. Alternatively, a long cast girder will carry the press and the bearings, as well as the driving motor. The biggest presses are supported on cross-girders bolted to a pair of longitudinal girders, and other cross-girders are provided for carrying the driving details. The depth of the pit depends on the operator's requirements for height, and for the projection of an extractor. The deeply based press seen in Fig. 45 is the one which does the pressing of radiator cowls, as shown in Chapter 13, Volume 1.

CHAPTER 3

COINING AND OTHER PRESSES

Coining is a term embracing the cold compression of several classes of products. The blank being placed in a die which is closed, or practically so, becomes squeezed or die-forged into shape purely by the flow of the metal, great pressure being required for the operation. In its broadest sense the process is applied to forming coins, medals, dials, embossed plates, spoons, forks, knife handles, turbine blades, watch cases, links, etc., and to the sizing and planishing of stamped objects. Apart from any question of forming, many metals are strengthened and made more resistant to wear as a result of the compressive action, and subsequent machining operations are often rendered unnecessary. In order to obtain the high pressures without spring or deflection, or damage to the dies, an extremely substantial type of framing is essential, and the mechanism must also be very strongly constructed, as considerable overloads are liable to occur, and the possibility of these must also be taken into account. The heaviest machines give a maximum pressure of 3,000 tons, and as a consequence special features must necessarily characterise the design and construction of coining presses, these not

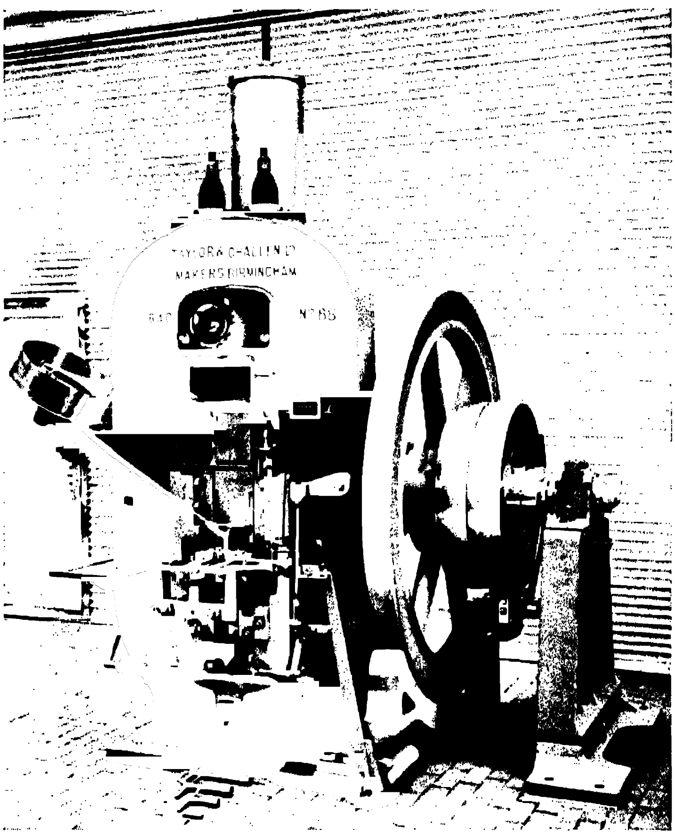


Fig. 46.—Coining press fitted with automatic hopper feed.

being usually found in other types of press, nor indeed would they be suitable to them.

Principle of Operation.—The coining press has to exert a heavy pressure, increasing towards the end of the stroke, and since the area of the work is comparatively small a very close design of framing can be employed. In the smaller sizes a solid closed frame is used (Fig. 46), the built-up tie-rod construction being employed for larger sizes, a steel casting or a steel forging being used in the former type with the gap for the slides and dies machined out. The methods of operation and the means of adjustment which are applied to other kinds of presses do not suit the exceptionally severe duties incurred in coining, and the slide is moved by a toggle or knuckle-joint device, being adjusted by a wedge that gives solid metal-to-metal contact. Two forms of knuckle joint are to be found in the different designs of coining press. In one, Fig. 47, the connecting rod from the crankshaft is pivoted on each end of a pin lying between the knuckles, which are free to swivel on the pin above and below. The pins and bushings are hardened and ground, and plentifully cut with oil grooves, through which the lubricant is distributed from the passages to which it is supplied by a pump, the flow returning to the pump from the bath in the slide block. The other scheme embodies the use of renewable toggle blocks, which are carried in holders provided with bearing pads for them to rock against (Fig. 48). Other features which may be observed in this drawing are: A, the top adjustment which is effected by a screw-actuated wedge; B, the pressure adjustment to bottom die; C, a setting to regulate the lift of

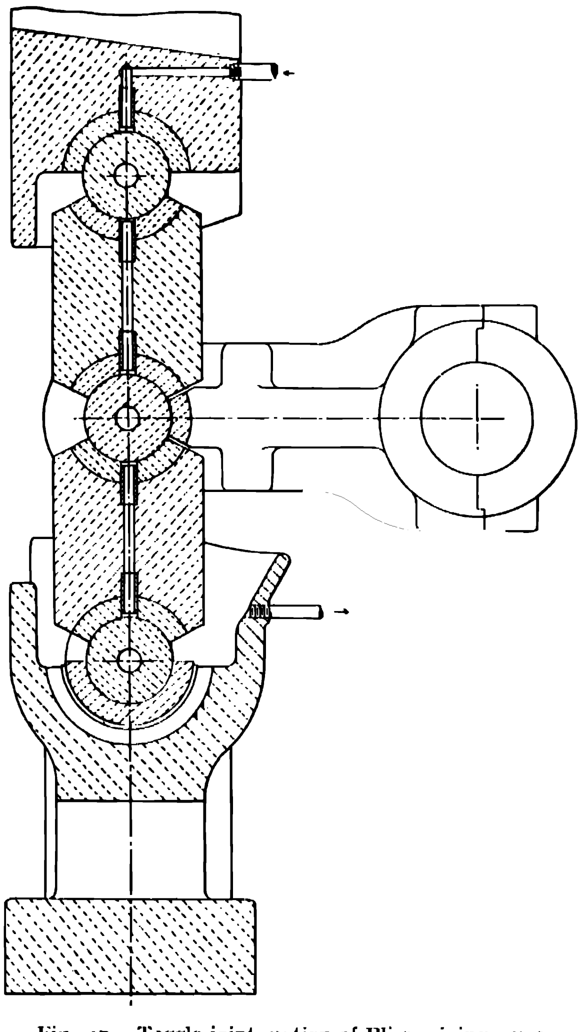


Fig. 47.—Toggle-joint motion of Bliss coining press.

the bottom die; D, a spherical seating, which permits of adjustment to the die-face level in order to equalise the impression on the work; E, the top die holder, which is removable and replaceable quickly without any resetting of the die; F, the cams, which lift bottom slide and eject the coin; G, the spring balance; and H, the delivery chute. The feeder chute has a connection with the automatic clutch, which stops the press when there are no more blanks left, thus preventing the dies from being damaged by clashing

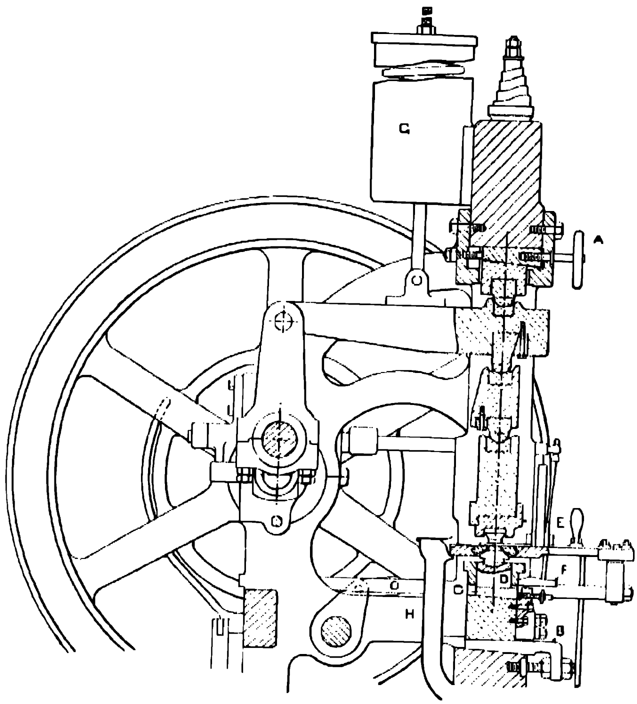


Fig. 48.—Taylor & Challen coining press.

The latest type of press, which is illustrated in Chapter 13, Vol. I, differs from the usual construction in that the top die is carried in a hammer lever instead of a slide, which renders the press more immune to the effect of a coin with irregular relief. The adjustment to the top die is effected by four parallel screws in the centre link of the toggle movement, and knuckles of the roller type are fitted. A lifting gear is provided for use when removing the collar plate to change the collar or bottom die. The particulars of this machine are:

Pressure exerted at bottom of stroke	250 tons
Stroke	$\frac{7}{8}$ inches
Adjustment to slide	$\frac{1}{2}$ inch
Strokes per minute, usual	80
Floor to collar plate	36 inches
Motor	10 h.p. at 720 r.p.m.
Overall height	124 inches
Net weight	$121\frac{1}{2}$ cwt.

The extractor mechanism shown in Fig. 49 enables a press to run at high speed, as many as 140 strokes per minute being obtained. The action of the extractor mechanism is as follows: The cam A on its forward stroke impinges on the pivoted pawl B and produces an upward movement to the bolster slide C, which carries the lower die, thus ejecting the coin to the level of the feed table from which it is swept off by the

feed fingers (not shown), sliding down the sloping table into a receptacle. The feed fingers immediately place another blank in the space in the collar formed by the falling of the bottom die.

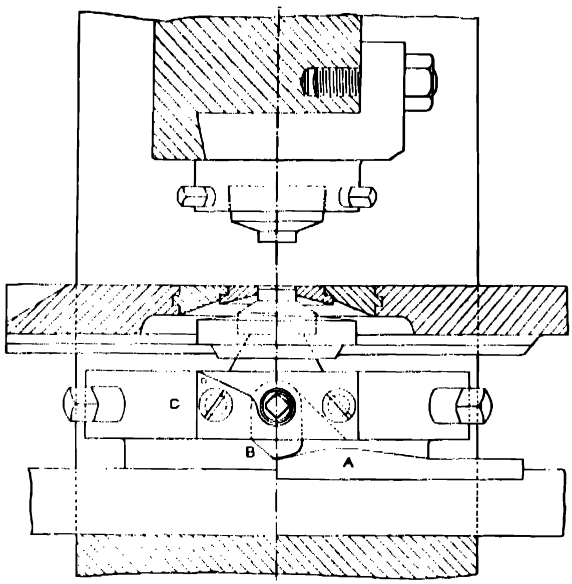


Fig. 49.—High-speed extractor mechanism of Taylor & Challen coining press.

Hand-feeding Attachments.—When hand feeding has to be performed, an attachment with lever-fed slide is provided which transfers the blank to the die as soon as the previous piece has been ejected, an interlocking device preventing the press from starting unless the feeder slide has been pulled right back. In the case of an embossed object having a centre hole, a central locating plug becomes necessary, the work being placed by hand upon this, extraction being by means of a hand lever. When a chute feed is employed, a special feeder can be fitted to deal rapidly with small coins. The feed fingers close together, allowing a very slight clearance for the blank, but in addition there are two cover plates, which are clear apart when under the coin chute, but overlap the coin when it feeds forward, and so prevents it from jumping out. A twisting device is provided which gives a turning movement to the top die whilst coining is being done, thus enabling the pressure available to produce a clear impression with the least possible pressure on the dies.

Preparation of Blanks.—The blanks are punched out in roll-feed presses using single or multiple punches. In a machine having three punches, the output is 450 blanks per minute, each $1\frac{1}{8}$ inch diameter by $\frac{1}{16}$ inch thick, a marking machine employing a rolling process thickening up the edges of the blanks before they are fed to the coining press. With an automatic rotary hopper feed the blanks can be put in haphazard, and they will separate themselves and pass down a chute to the marking wheel at the rate of 600 per minute.

Testing Machine for Coining Presses.—In order to determine the pressures required to produce perfect coins when new designs are in preparation, Taylor & Challen supply a hydraulic press, working up to 200 tons, and driven by a pump arranged on the same bedplate as the press itself. The bottom die and the collar, together with the blank which is inserted in the collar, are moved upwards by the ram until

contact occurs with the top die, the gradually increasing pressure being shown on the gauge, in tons and fractions of a ton.

Automatic Feeds.—Blanks other than coins and medals require various kinds of automatic feeds, the type chosen depending on the shape of the piece. A modified type of magazine and pusher feed can be arranged in many instances, or a chain feed may be more suitable. The turntable method is also applicable for some articles. Another system is to have a smooth rotating disk upon which the attendant places the blanks; as the disk rotates the blanks travel round to a stop gauge, and they are then successively pushed to the die by a swinging finger.

Horning or Grooving Presses.—The closing of side seams demands the services of presses or grooving machines, the differences in the mode of operation depending upon whether dies or grooving rollers are used. In the tinsmith's small grooving machine, hand gearing is employed to wind the roller along the seam, the same principle being employed in power-driven types. As an example of the power-driven type, mention may be made of a machine for handling pipes up to 3 feet long which has belt and gear drive, with instantaneous stopping, starting, and reversing motions. The grooving bar is pivoted and evenly balanced, and when the roller carriage has reached the end of its travel it automatically unlocks the end of the bar, which tips downwards, thereby enabling the grooved pipe to slide off. In order to obtain maximum output, the reversing motion is adjustable so as to give only the required length of travel necessary for the article, no matter whether this be long or short.

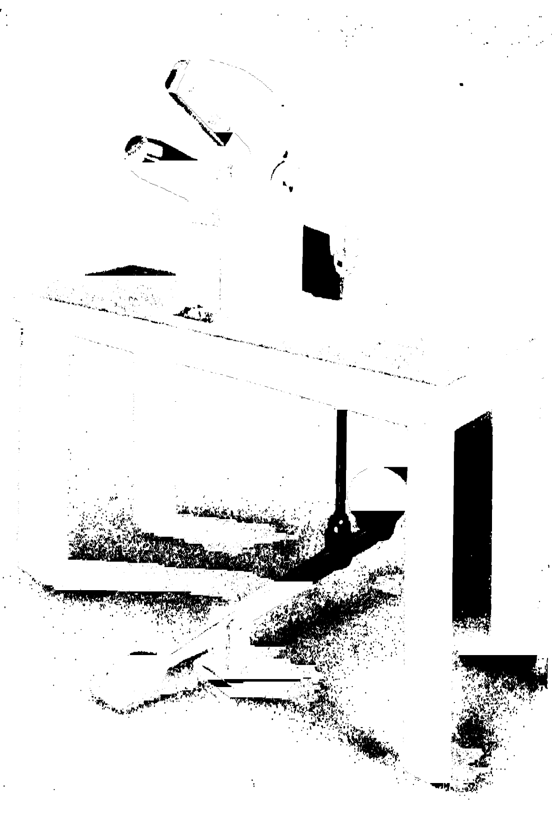


Fig. 50.—Foot-lever grooving press. (Rhodes.)

Horning Press.—The usual form of foot-operated horning press consists of a narrow frame bolted on the bench, carrying a pivoted arm with a blade which comes down when the pedal is depressed. The horn lies at an angle to facilitate placing on the work, and different horns

are substituted according to diameter, while various-shaped horns, either round, elliptical, or of any other desired form, can be used (see Fig. 50).

Power-driven presses are sometimes of normal width, when used for general purposes, and the table is removed or swung aside (Figs. 51, 52) for the insertion of a horn. When specially built for horning, a narrow frame is suitable, and the horn is fitted into a hole or bolted against the face.

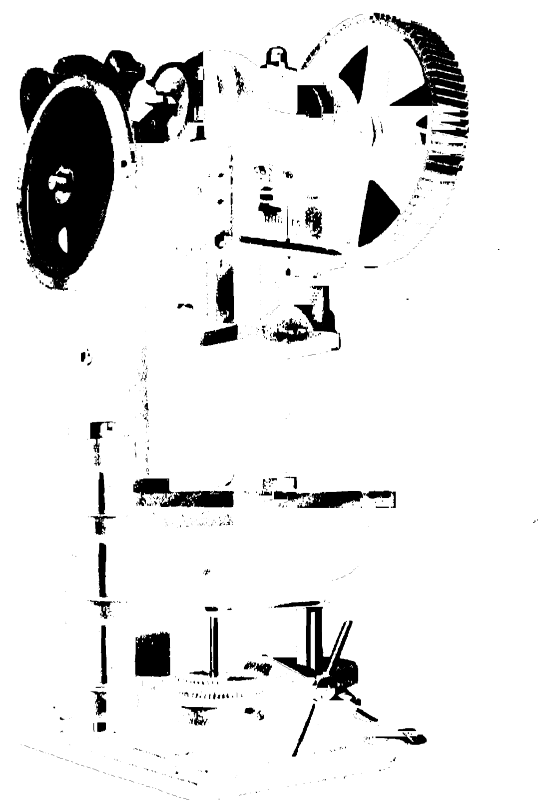


Fig. 51.—Large horning press with heavy swivel table. (Rhodes.)

A double-horn press is made for use in the construction of 5-gallon tins which horns two body seams simultaneously. Wide presses are supplied for certain purposes, such as closing the sides of perambulator bodies, the boxes of grass cutters and so on, a two-crank model dealing with these. An end-wheel type of press is employed for heavy work, such as kegs and drums, the horn projecting from a lug cast on the frame, with the slide reciprocating in guideways, similar to the practice adopted in punching presses (Fig. 53). Another mode of operation, for long articles, is to extend the driving shaft under an arched frame, the outer end of which sustains the shaft, while the long ram moves in guideways at each end. Two eccentrics actuate the connecting rods pivoted to the ram.

Folding and Grooving Presses.—The complete process of folding and closing is performed in machines of the end-wheel type, which have bending bars and pressure bars (Fig. 54) moved by cams, with automatic support to the mandrel, which leaves it open at the proper time, but sustains it during the folding and grooving operation. An inclined-horn press (Fig. 55) is built on somewhat similar lines, both styles being made

in three sizes which handle lengths of 5, $8\frac{1}{4}$, and $10\frac{1}{2}$ inches respectively, the smallest diameter of body being $2\frac{1}{8}$ inches.

Seaming Machines.—A large variety of machine types are employed in the operation of seaming the ends of cans, drums, boxes, etc., these being either small or large, hand, semi-, or fully automatic, some being fitted with dies, while others have rollers. Some of these machines do only one end at a time, while others are designed to do both ends simultaneously. Machines for combined flanging and seaming are described in Vol. 1, Chapter 12.

Hand Seamers.—The lightest class of seaming machine is held in a support on the bench, and has double arms in which run the spindles, with a setting-down motion operated by either a handle or a screw for the upper one. The smallest-capacity machine of this type is designed to handle work from 10 inches deep and downward to $2\frac{3}{8}$ inches diameter. Another bench pattern obtains the pressure from a foot-operated lever, and is equipped with a set of supporting disks in standard sizes: straight—5, $5\frac{3}{4}$, 6, $6\frac{1}{2}$, and 8 inches; taper—$4\frac{1}{8}$, $4\frac{3}{8}$, $6\frac{1}{4}$, $8\frac{5}{8}$, and $10\frac{7}{8}$ inches. In another instance the pressure of a hand lever forces over the rollers, the drive being either by hand, wheel, or belt pulley. The chucks and rollers are reversible, so that when one end is worn the other end can be used, giving double life. Tops and bottoms of cans from 2 to $6\frac{1}{2}$ inches diameter and from 2 to $8\frac{1}{2}$ inches high are dealt with. Fig. 56 shows this machine.

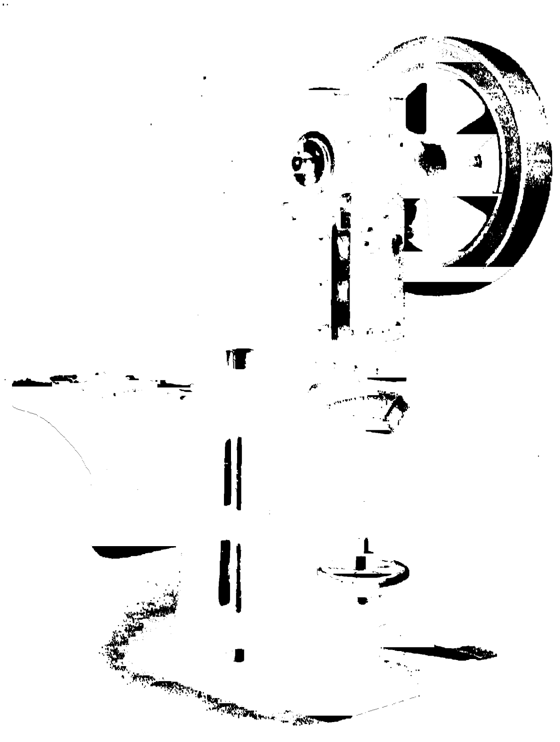


Fig. 52.—Horning press fitted with swivel table for wiring.

Power-driven Seamers.—These are of the vertical pattern, and are available in the semi- and fully automatic types. In some of these the body is rotated, while in others the body is stationary while the seaming process takes place. The simpler designs embody a column with a top spindle driven by a belt pulley, or a belt pulley in conjunction with gearing may be employed, control for the rollers being by means of a

lever. Spiral gears afford the smoothest form of drive to the spindle, particularly if a friction clutch is incorporated, working in conjunction with a brake. The latter is to stop the spindle instantaneously, it being more convenient to clamp cans, especially large ones, while the spindle is stationary. The approximate output for medium-sized cans would be about 1,500 per hour.

Fig. 53.—Rhodes' horning press for kegs and drums.

Another hand-pressure seamer has the lower spindle driven through bevel gears from the pulley shaft, the upper disk being pulled down by a lever. This deals with vessels up to 18 inches diameter by 24 inches long, made in 20 s.w.g. sheet, the output being from sixty to seventy-five per hour. In a heavier construction, having the pressure applied to the seaming rollers by screw and hand wheel, about fifty drums per hour can be handled, the limit of dimensions being 30 inches diameter and 42 inches long, the power required to drive the machine being $7\frac{1}{2}$ h.p.

A sliding table (Fig. 57) is provided for operating the internal chucks required for seaming the cones on tin bottles, or, alternatively, the table is constructed so that it can swing. Sometimes a rim-rolling attachment is included, enabling a body to be seamed on the bottom, and wired on the rim.

Fig. 54.—Action in automatic side-seam locking machine. (Moon Bros., Ltd., Birkenhead.)

Mechanical-pressure Seamers.—Instead of forcing up the rollers by a hand lever, cam action is arranged in a good many different types of machines, the cam functioning when a treadle is depressed (Fig. 58). One such machine will give an output of about 100 gross per day, up to 7 inches diameter. A modified design handles square, elliptical, and

irregularly shaped tins. The same idea is to be found in machines handling vessels of large capacities; for example, drum seamers are made for diameters up to 24 inches, the drum being placed on the chuck mounted on the adjustable table, which is raised by a lever, while pedal control starts the drive. The pressure is regulated for various flange widths, and there is an arrangement which ensures tight seams even on containers having grooved side seams. The following are the brief particulars of the largest model:

Fig. 55.—Inclined horn type of folding and grooving press. (Rhodes.)

Maximum diameter of drum	24 inches
Minimum diameter of drum	11 inches
Maximum length of drum	42 inches
Minimum length of drum	10 inches
Maximum gauge of metal	14 s.w.g.
Power to drive	15 h.p.

Safety Guard.—To prevent risk of the operator being injured by the lid flying out, a wire guard may be attached to the machine, this being pivoted to rise out of the way during loading. As soon as the clamping has been done, and before the drum turns, the guard has dropped automatically to the safety position, where it is locked by a cam. The act of de-clamping automatically raises the guard clear for removal and reloading.

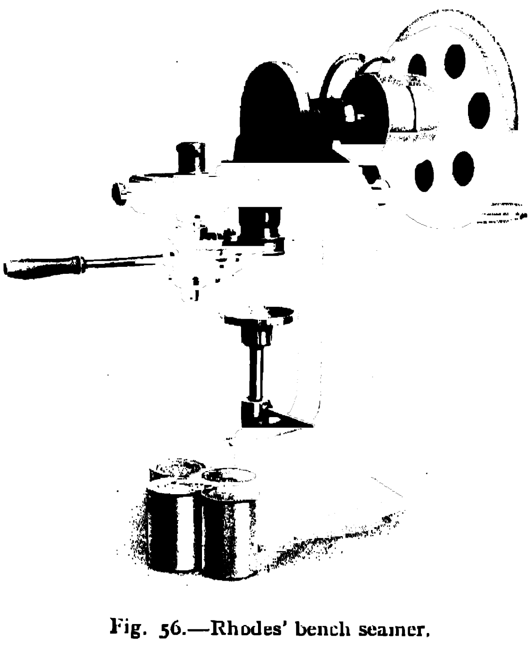


Fig. 56.—Rhodes' bench seamer.

Continuous Feeding.—Two operators secure a rate of five drums per minute on a four-platform drum seamer, the units being brought around automatically to the seaming position. The turntable is rotated and stopped by means of a worm-operated Geneva motion acting directly on the turntable spindle. There is an attendant at each side, one to feed and the other to invert the drums after one end has been seamed, so that they are ready for seaming the other end. The sizes handled

are, diameters 16 to 22 inches, and lengths 19 to 36 inches (see Fig. 59).

Stationary-body Machines.—A different class of seamers performs the action by means of four rollers in the spindle, whilst the body is stationary. There is no torsion, as with revolving cans, and no side pressure is put on the spindle; moreover, when seaming containers which have already been filled the contents remain undisturbed. The rollers comprise two first-operation and two second-operation shapes and the first pair tuck the can end edge under the flange of the body and slightly curl both of them inwards, and the second pair follow and flatten the seam tightly. About 2,000 cans per hour can be seamed by machines of this type, elliptical and rectangular, as well as irregular cans, being also seamed by this method. A heavy type of machine handles cement drums, etc., up to 24 inches diameter, seaming on the tops after they have been filled. The counter-balanced spindle works in an arm standing out from girder uprights, and a long hand lever controls the descent of the spindle. Fig. 60 shows a machine for petrol tanks, and Fig. 61 one for closing filled cans.

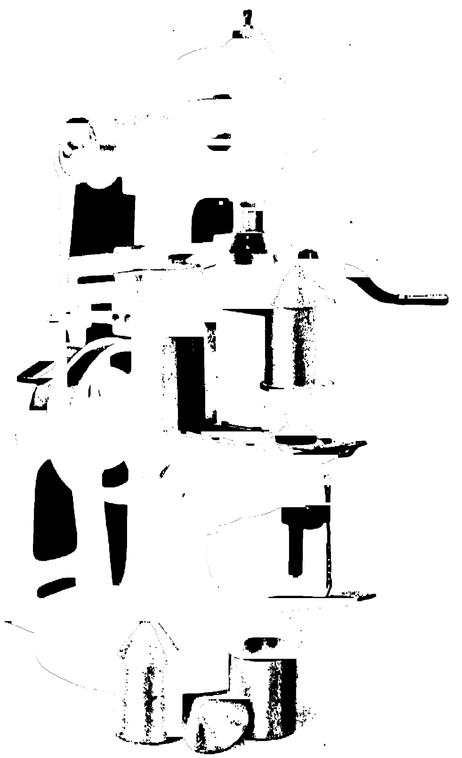


Fig. 57.—Double seamer provided with sliding table for operating internal chucks. (Rhodes.)

Automatic Lid Feed.—A magazine-feed attachment to the stationary can seamer eliminates the necessity for hand placing of lids or bottoms. The lid reaches the can, and both are held by spring pressure against the chuck, about 2,000 closures per hour being obtained.

Full Automatic Machines.—The combined working of a rotary and slide feed for bodies, and a magazine feed for lids, is seen in an automatic machine that attaches the lids to empty or filled cans at the rate of one per second. It has a positive no-can, no-cap device, and a marking apparatus for the caps. Diameters from 2 to $4\frac{1}{4}$ inches are handled.

A speed of 150 empty cans per minute is secured on an automatic machine which has four seaming heads for the circular seams, and four for the longitudinal seams. When seaming on lids of filled cans the output is

about eighty per minute, and the cans, which are tranferred by a conveyor to the heads, do not rotate. On a certain job two machines are employed; on one machine the top being seamed, and the can automatically inverted, when it is conveyed to the second machine where the other end has to be seamed, the output being 12,000 square cans per day.

Simultaneous Seaming.—Some machines will perform the seaming of tops and bottoms simultaneously, special seaming roller guides accommodating differences in height due to faulty shearing or flanging. The seams come out clean and regular, and the body does not suffer twisting.

Seaming by Dies.—The direct stroke of a die in a power press may be applied to close seams, and there are squeezer machines that seam flat tops and bottoms on to bodies of petrol cans, biscuit tins, and such like. A mandrel holds the tin internally while the flat die slides approach at stations 90° apart. To seam the bottoms to round or rectangular tins a machine with an internal chuck and vertically moving die is employed, turning out one per second. Automatic action takes place as the bodies feed along a conveyor.

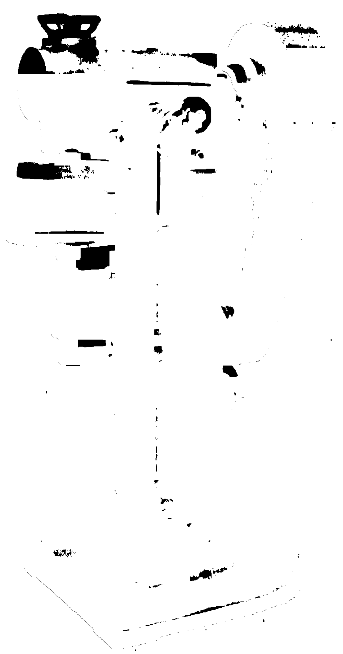


Fig. 58.—Mechanical-pressure double seamer. (Lee & Crabtree, Ltd.)

Crimping Machines.—Crimping or single seaming is effected both on roller-pressure machines and on those having dies. Some roller crimpers do one end at a time, others both ends simultaneously, all of them being of the belt-driven types. The die squeezers work by foot, or power drive, the dies sliding on a flat table, ordinary single seams, as well as hemmed-edge seams, being closed in this manner.

Wiring.—This process covers the curling or false wiring of edges, in addition to the real wiring, in which a wire is enclosed, and machines with rollers as well as presses using dies are variously employed. A large amount of work of this nature is effected in power presses using curling or wiring dies, the resulting shape being a circular curl, or a flattened or clenched section, depending on the particular purpose for which the job is required. The curling die is so shaped that it causes the edge to roll up into a recess hollowed in the die, and although many sorts of work can be done in the usual kind of press, deep objects necessitate the provision of a special bed or table.

Wiring Presses.—The various types of wiring press exhibit differences as regards the design of the beds in which an increased depth is afforded

by the employment of either fixed type of bed construction, or through the use of an adjustable table. The movement necessary to bring out the die for the reception of the work is afforded by a slide working between gibbed guides. Some of the double-sided presses are furnished with a sunken or U-shaped bolster deep enough to take the die, the sliding movement being obtained in the same manner.

A press specially built for wiring deep articles, such as buckets, dust-bins, gas-boiler casings, etc., has the drive taken from a shaft arranged underneath the bed, crank-pins operating the rods which reciprocate the slide in a tall frame (Fig. 62). The dimensions of a bucket-wiring press of this description are: stroke, 14 inches; distance between uprights, 22 inches; maximum clear opening, 30 inches; bed, front to back, 20 inches; diameter of top platen, 17 inches.

Fig. 59.—Continuous-feeding drum seamer. (Taylor & Challen, Ltd.)

Roller Machines.—Wiring may also be accomplished in the spinning lathe by the pressure of rollers, and there are several kinds of machine which curl or wire by a formative method of this description. Tinsmiths use the little bench machines turned by handle, and at the opposite end of the scale are the large automatic machines capable of taking plates or trays, chucking and curling them at a rapid rate. Edge-curling attachments often form a part of the machines used in the production of lids and bottoms for can-making, being located at the rear of the blanking and stamping presses. The curl enables automatic stacking and feeding to be done for subsequent operations, and the curl protects the sealing ring, which is later inserted. The attachment has an outer stationary ring and an inner revolving disk, driven from the main shaft of the press. The outer ring is mounted eccentrically in relation to the inner one, so that the can ends entering between them at the wide point will be forced to rotate by the inner disk, and to pass through a passage which gradually becomes narrower, thereby producing the curl. The rims of the outer ring and inner disk

have grooves of the shape required to form the curl. If all the lids are accurately curled a counting apparatus can be used to separate them automatically into batches of 100 as they slide down a chute.

Wiring and Edging Machines.—A comprehensive series of operations is performed by the Magee wiring and edging machines, which drive rolls of appropriate contour for the purpose. Those for wiring and edge turning respectively are shown in Fig. 63, adjustments being made

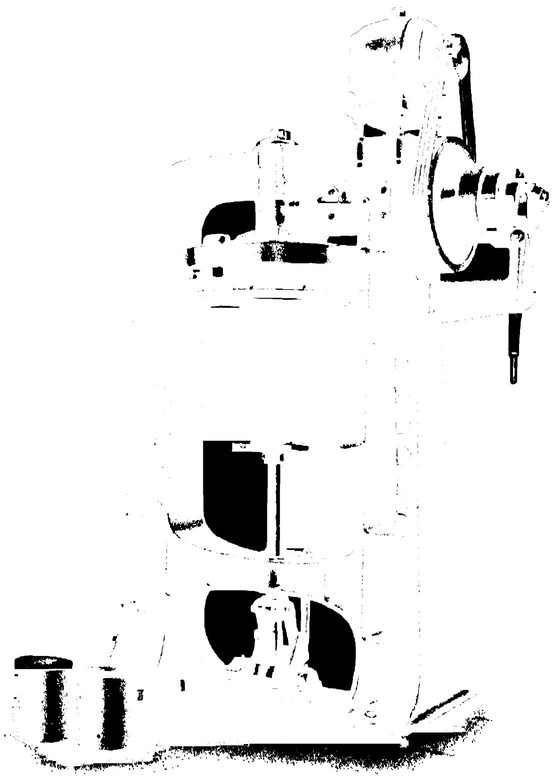


Fig. 60.—Semi-automatic double seamer of stationary body type.

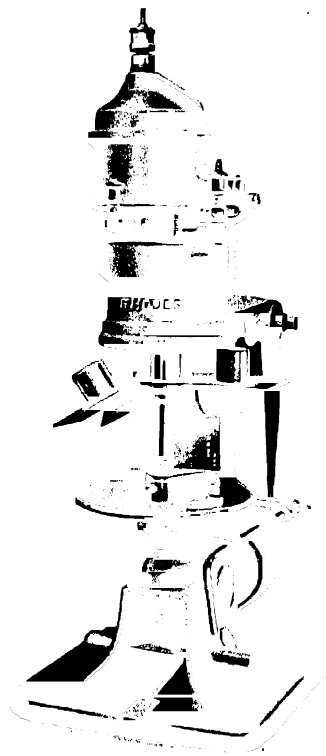


Fig. 61.—Semi-automatic seamer for filled cans.

according to the distance required between the peripheries and the shoulders of the rollers. Specimen operations are shown in Fig. 64, and the capacity of the machines is such that they will wire a length of one mile in eight hours. Three sizes of machines are built, and there is also a special design for wiring internal circles. Eight standard types of hinged sub-frames or heads are supplied, so constructed that they can be quickly interchanged, leaving their set-ups undisturbed, and thus a rapid change-over from one job to another can be effected. A dial gauge is used for instant micrometer settings. Fig. 65 shows a general-purpose machine

in which the motor is disposed in the column base. The heaviest size will take sheet up to 14 gauge, and wires to $\frac{5}{16}$ inch diameter. A combined action may be obtained by the use of what is termed a disappearing roll, permitting the set of rolls to wire and bead at the same time at any point simultaneously with the wire, and also to terminate anywhere irrespective of the wire.

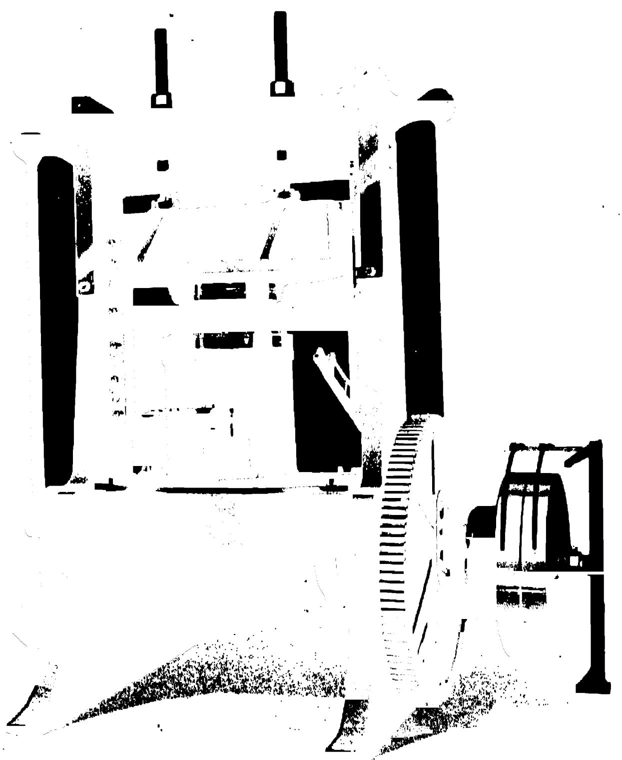


Fig. 62.—Press for wiring buckets, dust-bins, etc. (Lee & Crabtree, Ltd.)

Deep-throat Machines.—Fig. 66 shows the special type of machine built for wiring internal circles. This avoids the undesirable necessity of cutting through the sheet from the outside, and welding the parts together after the wiring has been completed, which method is, moreover, liable to change the shape of the sheet as it passes through the rolls. A hole as small as 7½ inches diameter can be run, and as large as will go through the throat, which is 31 inches, measured horizontally, which gives an outer circle diameter of over 5 feet. The driving and operating mechanism are similar to those in the machines previously described.

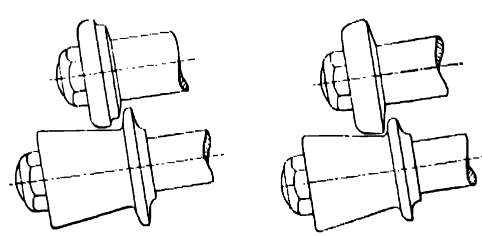


Fig. 63.—Rollers for wiring and edge turning.

Wheeling Machines.—Other classes of machines which employ rollers comprise the wheeling machines, and weld-crushing, rolling, and seaming machines. The first named is a simple affair (Fig. 67) which is utilised chiefly for smoothing and taking out creases from work previously shaped, such as motor wings and panels, although it is sometimes used for formative operations as well. The main shaft, which is turned by means of the

handle, runs in ball bearings, which are also fitted to the inter-changeable bottom rolls. A quick rise-and-fall movement to the bottom roll allows for the removal of the work without altering the pressure adjustment. The average depth of gap is 40 inches, and attachments may be fitted for beading, seaming, and weld crushing.

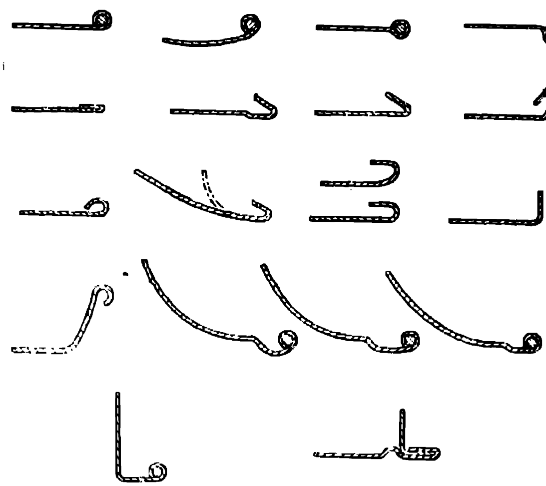


Fig. 64.—Some of the shapes done on the wiring and edging machine.

Weld-crushing and Rolling Machines.—The distinct operations of rolling, crushing, and seaming are effected on a machine constructed by the Oliver Machinery Co., Ltd., the change to any one of these operations being quickly effected. The frame is composed of two portions, the upper main element having slide adjustment by hand wheel to accommodate the setting of the seaming rolls, while the front section of the frame overhangs to permit a circular wing to pass underneath, the back part of the upright holding the driving mechanism. Both the top and bottom rolls are power driven, the former through a special jointed shaft, the latter by chain. The top roll has a quick vertical movement obtained by the use of a powerful ratchet lever, the bottom roll being raised similarly. The bottom roll may either be driven or allowed to run free if desired, a chain drive being adopted in order to

Fig. 65.—General-purpose wiring and edging machine. (Oliver Machinery Co., Ltd.)

enable welded work to be passed through between the rolls at right angles. A removable bracket is attached to the bottom ram, and carries auxiliary rolls in order to permit of welded sections being rolled in a straight line. The 3-h.p. motor transmits the power through a Texrope, the reversing motion being obtained by means of a switch, while the control of the drive is effected through a clutch on the main shaft worked from pedals at each side of the machine (Fig. 68).

Riveting Machines.—Although much of the jointing in sheet-metal work has in recent years been subjected to a complete revision of methods necessitated by the great extension in the use of welding, there is still a considerable amount of riveting done, and various kinds of machines are installed for carrying out this work, the design of which depends on the size and class of work, and the quantity to be handled. Some objects are soft or delicate, demanding special care in riveting; again, there are jobs which can best be united by the use of a row of rivets, and all of these may be closed at one blow. Diversity necessarily exists in the shape of the frames used in the design of riveting machines, on account of the various shapes of work which have to be handled, but in many instances an otherwise ordinary press will be equipped with a special table, or anvil, or horn, to enable it to be used for riveting work. Hand or foot presses are used for light work (Fig. 69).

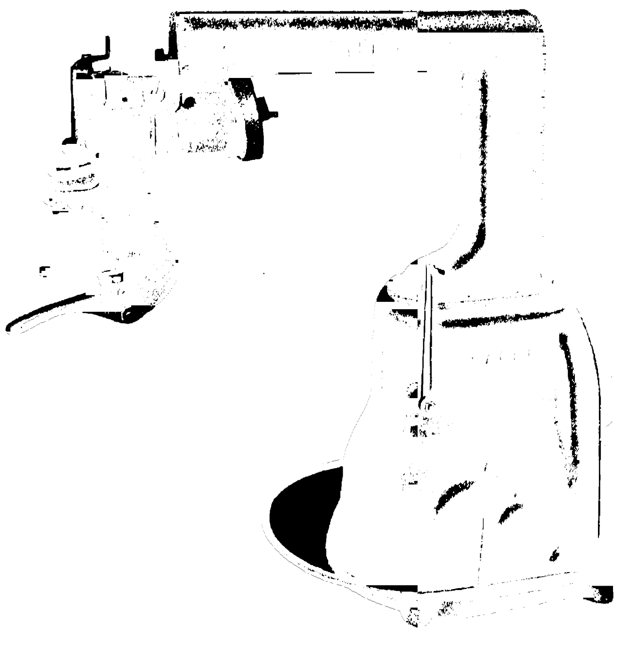


Fig. 66.—Deep-throat wiring and edging machine for internal circles. (Oliver.)

Small Riveting Presses.—One of the simple types of riveting machine is that in which an eccentric end wheel is employed to deliver a single blow, an anvil of suitable shape being fitted on the bed (Fig. 70). Control is obtained by means of a pedal clutch. In this machine the reach from the centre to the back is 5 inches. Another single-blow press has a horizontal rocking arm at the end of which the snap is fastened, and the support lies in an adjustable slide overhanging the frame, components

difficult to manipulate being thus handled more easily than on an ordinary press. The riveting arm is rocked by an eccentric on the driving shaft close to the floor, and a rod connects to the tail of the arm. Rivets from $\frac{3}{16}$ to $\frac{7}{16}$ inches diameter can be driven on this machine (Fig. 71).

Window-frame Press.—For riveting steel window frames an end-wheel press, or one of the lateral-shaft type, is employed, the anvil being bolted to the facing on the standard with two screws for adjustment and prevention of slip (Fig. 72).

Tank Riveters.—For closing rivets in tanks, drums, and pipes a long mandrel must be employed extending from the press frame, and the end-wheel type of press is therefore used (Fig. 73). Mandrels range in length from about 3 to 6 feet, and the presses will close $\frac{5}{16}$-inch diameter rivets. A modified form of anvil is required to reach through a manhole and support the tank. To rivet up the ends of tanks a tall-framed press is required, and the long anvil, which is made of square section, tilts outwards on a pivot to facilitate removal of the tank, bodies having a depth up to 38 inches being accommodated.

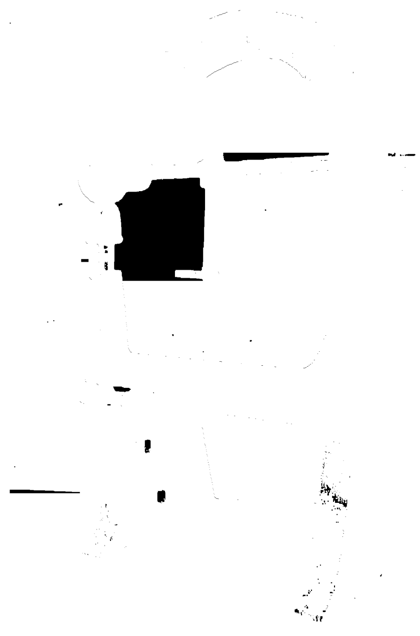


Fig. 67.—Wheeling machine for smoothing purposes. (Walter Frost.)

Bucket-riveting Press.—For this work a press carrying a long anvil and the necessary closing tool is employed. The rivets are placed in position by a charging device, the first stroke making the rivets pierce their holes, while the second cups and flattens them. Employing two operators, sixteen gross of buckets can be riveted in a day.

Rotary-blow Machines.—To increase the rate of production, and at the same time to ease the action of riveting, some machines embody a rotary motion combined with high-speed vibration. Both top and bottom anvils are driven, although the bottom one can be rendered inoperative if desired. A high-speed riveter incorporates a set of rollers running between revolving disks, and centring themselves by centrifugal force. The work is laid on the anvil and raised by a pedal, the punch moving upwards until it comes into contact with the rollers. In combination with the rotary action the rivet receives 10,000 blows per minute. Four models of this class of machine are available, the particulars being as follows :

Capacity, diameter of head . .	$\frac{17}{64}$ inch	$\frac{1}{4}$ inch	$\frac{7}{16}$ inch	$\frac{5}{8}$ inch
Time required per rivet, seconds .	2 to 3	2 to 3	4 to 5	6 to 7
Power required, h.p. . . .	·3	·4	·8	1
Maximum distance, punch to anvil	$2\frac{3}{8}$ inches	$3\frac{3}{8}$ inches	$5\frac{1}{8}$ inches	$5\frac{1}{8}$ inches

An imitation of hand riveting is obtained in the Churchill machines, which are built in sizes for $\frac{1}{8}$-inch and $\frac{5}{16}$-inch rivets. Reciprocating motion is imparted to the hammer spindle by a hickory helve, pivoted on to the head casting, and actuated by a thrust block working between rubber buffers. A connecting rod goes through the thrust block, to transmit the motion from an eccentric on the main spindle. This method gives a series of sharp, definite blows, the spindle at the same time being rotated by means of a worm gear. A disk clutch with fibre lining is located in the main pulley, and controlled by a pedal, a brake which stops the hammer spindle in its highest position coming into action automatically on releasing the foot. Either countershaft or motor drive may be employed; in the latter case, a three-speed pulley permitting the hammer to deliver approximately 3,000, 2,150, and 1,540 blows per minute. A standard design of table is fitted, although a special form for irregularly shaped objects can be supplied if desired. The smaller-capacity machine requires $\frac{1}{4}$ h.p. to drive it and the larger one $\frac{3}{4}$ h.p. Fig. 74 shows a helve riveter.

Fig. 68.—Weld-crushing and rolling machine.

Spinning by the pressure of little rollers on a revolving spindle constitutes another mode of closing rivet heads.

Automatic Riveters.—The full development of light riveting practice is seen in an automatic machine which will place and head from 1,200 to 2,500

rivets per hour (Fig. 75). A hopper feed, with positive selector gear, supplies the rivets to the work, the two parts of the latter being pressed together whilst riveting is actually in progress, thus ensuring filled holes with tight joints. A pilot guide gives quick setting, and solid, tubular, or split rivets can be used, the change-over being made in a few minutes to suit any size or type of rivet up to $\frac{1}{4}$ inch diameter and $\frac{7}{8}$ inch long. An auto-feed pedal machine appears in Fig. 76.

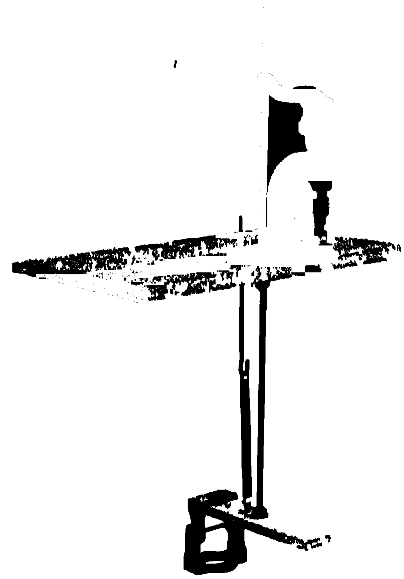


Fig. 69.—Foot operated riveting machine. (Bifurcated and Tubular Rivet Co., Ltd., Aylesbury.)

Trimming.—The trimming of raw edges left on various sheet-metal articles, which have been hand worked, rolled, stamped, or drawn, calls for the services of various kinds of machines, chosen according to the shape of the component, or the number of units which have to be passed through. The various types of spinning lathes are freely used for this operation, the trimming process being effected at the same chucking as that when spinning, beading, or wiring is performed, although sometimes the final process is carried out on another lathe. As already noted in Vol. 1, Chapter 10, rotary shearing machines can be used to trim curved and contoured stampings of any outline.

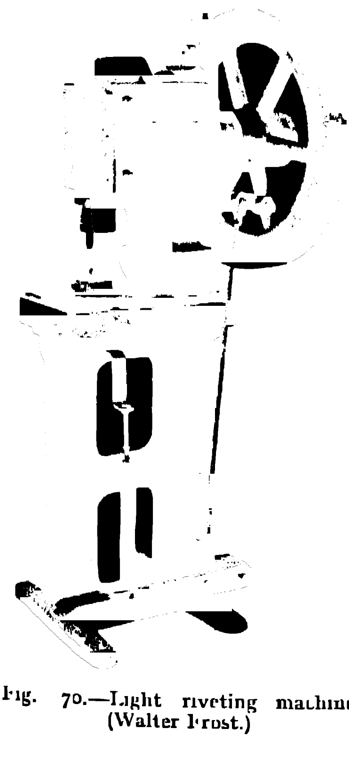


Fig. 70.—Light riveting machine. (Walter Frost.)

Trimming Presses.—Dies can be operated in the power press to shear off the edges of any sheet by a lateral movement. The Bliss trimmer, which is an example of this, is a double-sided press with cam motion to the slide, and the upper die (Fig. 77), which is ground with sharp cutting edges, has a filler pad free to float on its surface. The lower die has its surface ground truly, and the projections or gauge pieces surrounding the cutting part of the upper die ensure positive and accurate alignment between the respective cutting edges of the pair. On starting up, the cam motion

Fig. 71.—Riveting press for awkwardly shaped components. (Walter Frost.)

Trimming Machines.—Sliding-die motion is incorporated in machines which trim rectangular stampings, the dies lying horizontally, vertically, or in an inclined position as required. The last-named arrangement is adopted in a high-speed automatic box trimmer, capable of handling sizes up to 4½ inches square. The boxes are fed down a chute being placed on the trimming block by a slide, and, after the trimming process is completed, they are automatically ejected. The output of this machine is 200 gross per day. The horizontal and vertical machines possess four die slides automatically fed up and withdrawn, the stamping being clamped by a lever apparatus. One such type (Fig. 78) takes sizes forces the upper die down, and the filler pad, entering the piece, depresses it to the correct shearing level, where it remains during the actual trimming process. This is effected by movements of the lower die, front to back, right to left, after which the slide rises and the stamping is lifted out by the ejector, the scrap and the stamping being blown away by an air blast. The shearing strokes of the lower die are effected by a mechanism in the bed, worked from the main shaft. If the edges require to be finished with notched or irregular edges, the dies are shaped accordingly.

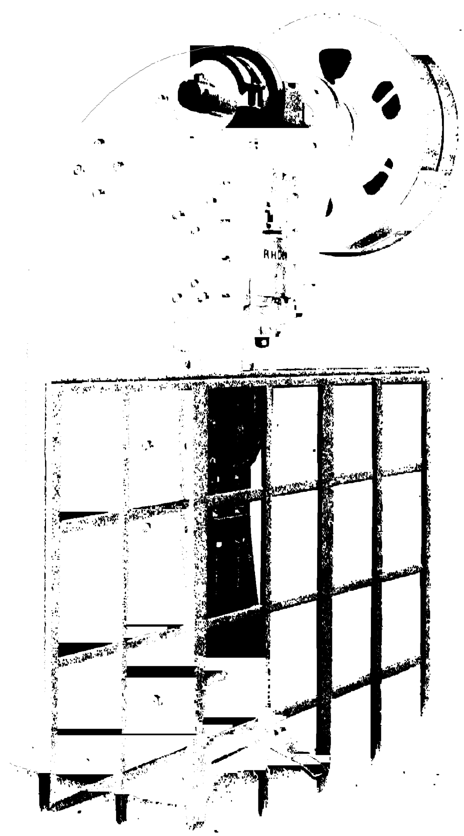


Fig. 72.—Rhodes' window-frame riveting press.

up to 11 × 11 inches, dealing with triangular and elliptical forms as well.

Trimming Lathes.—The inclusion of a trimming rest on a spinning lathe is a very usual practice, one cutter in collaboration with a stationary rest against the work being employed, or two cutters may be arranged in opposition. When no spinning is effected on the lathe, a simpler construction may be adopted (Fig 79), although very often another operation comes in, such as beading, bulging, or marking. To trim basins, bowls, saucepans, etc., a trimming and beading rest is mounted on the bed, lathes of various sizes up to about 24-inch centres being built in this way. A compound rest is, however, necessary for trimming and beading shells with flanges at 45°, this being the usual angle of the flanges when deep drawing is done. A Taylor & Challen 9-inch centre lathe is specially designed for trimming, beading, and flattening the edges of cinematograph film boxes. The stampings are chucked and held by a treadle-operated toggle mechanism; they are then trimmed by turning a hand wheel, after which a lever motion forces up the beading roller. When the trimming cutters are again fed up, flats arranged on the trimming cutters clench the bead into a flat shape. It may be noted that chucking and removal of the boxes is performed without stopping the lathe. A similar chucking process is employed in a lathe that trims and marks covers for saucepans, the marking roll bulging the metal out from the inside, two levers being employed to control the trimming and marking tools. For long, small cases, such as those for cartridges, a mandrel chucking is done by threading the case on to the mandrel and pressing it home by a lever. The trimming slide is moved with a lever, another lever being employed to remove the trimmed piece. By this means about fifteen pieces per minute can be trimmed, but a much higher rate is possible on an automatic lathe designed for similar duty, the cases going down a chute, at the bottom of which there is a revolving "spoon" which cuts off the supply while the rapidly revolving mandrel enters the case and feeds it forward to be trimmed.

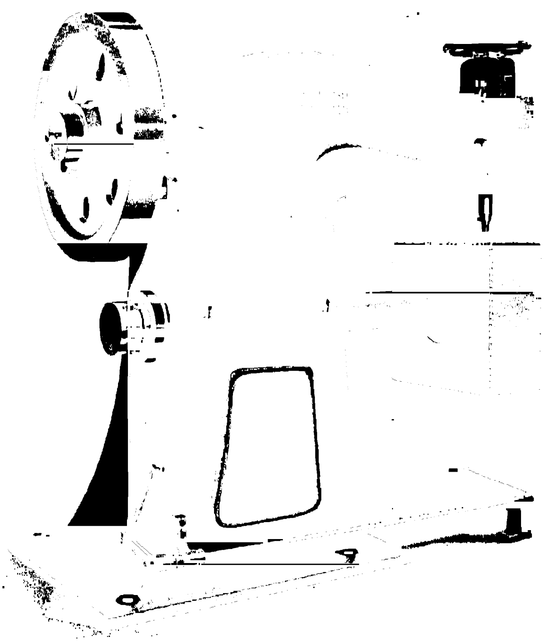


Fig. 73.—Tank riveter. (Lee & Crabtree, Ltd.)

Automatic Trimmers.—The resemblance to the lathe tends to disappear in some of the different designs of automatic trimmers which are available. One of the chute-feed types takes a case as it reaches the bottom of the chute, and moves it forward until it has entered a revolving die, whereupon trimming takes place. The mandrel retires, leaving the trimmed case in the die, from which it is pushed off

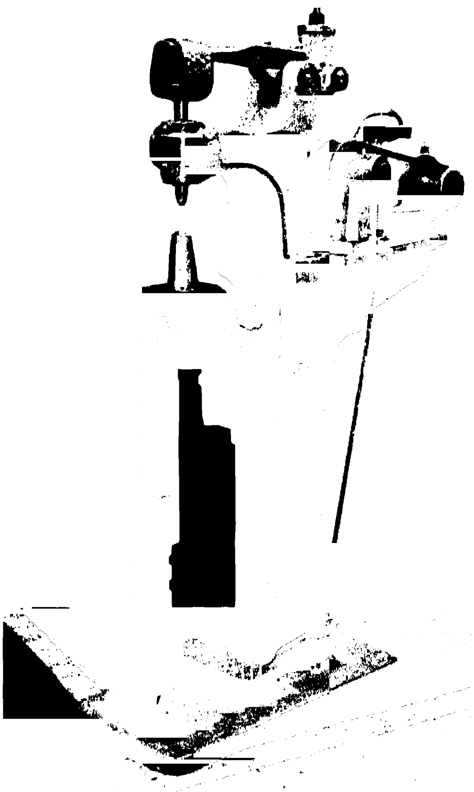


Fig. 74.—Elastic-blow riveter. (Burton, Griffiths & Co., Ltd.)

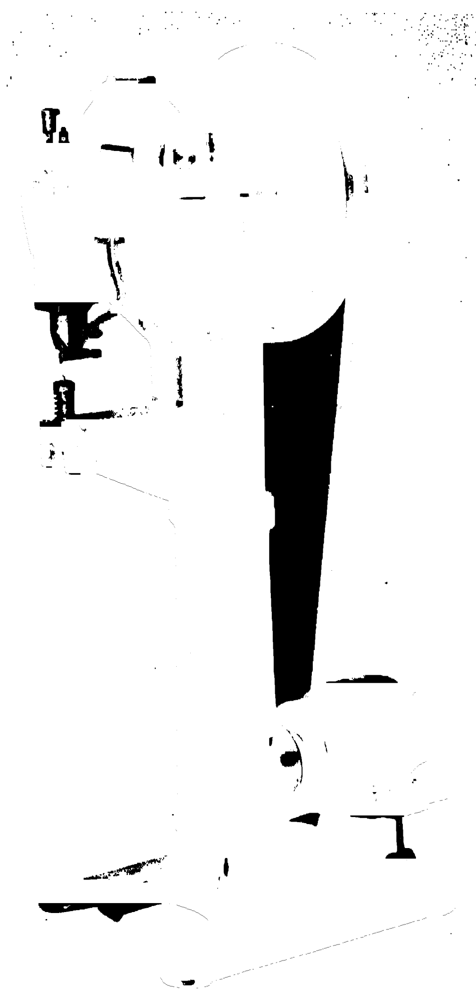


Fig. 75.—Automatic hopper-feed riveter. (Gaston Marbaix, Ltd.)

by an automatic extractor, to fall down another chute. The rate of production is sixty-four pieces per minute.

Barrelling.—A class of treatment which is somewhat related to trimming, but also goes beyond its scope, is that of barrelling, shaking, or tumbling. It is applied to the cleaning off of raw sharp edges on stampings and other pieces which have been cut, being a quick wholesale mode of accomplishing the process. Also of putting a smooth or burnished

finish on the articles, which may be sufficient for their purpose, or as a preparation for plating or other operations. Parts in iron, steel, copper, brass, gunmetal, nickel-silver, gold, silver, as well as bakelite and other plastics, are dealt with. Different methods are adopted according to the sort of goods. The principle is that of tumbling the objects in a rotating barrel, with or without an agent that will facilitate the action. Some shapes will mutually operate to effect the scouring process, others require mechanical assistance in the way of steel balls, iron rumbling stars, or steel scrap, which, however, can be used over and over again. The stars penetrate recesses.

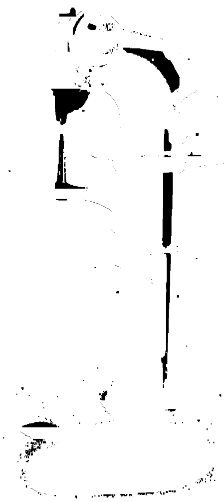


Fig. 76. — Auto-feed riveter, foot operated. (Bifurcated & Tubular Rivet Co., Ltd.)

The preliminary action of scouring is done along with cleaning materials. Iron and steel pieces, if they have scale, need emery and oil in the barrel, but clean metal only requires Tripoli powder, pumice powder, or fine sand along with water. Hardened-steel articles, if they will not barrel alone, are scoured by the addition of steel scrap; and sharp sand or granite chippings, along with a metal cleaner, impart a silvery-grey colour. Copper, brass, gunmetal, and nickel-silver are treated by powdered pumice and water, while another way is to use coke dust and water. The burnishing of soft-iron and steel parts is performed in a barrel along with a number of bright, hard steel balls, covered with water, and a little soap powder added. Aqua fortis is sometimes employed to dip copper, brass, gunmetal, and nickel-silver before giving the same treatment as just specified. The difference with regard to silver and gold is that the cleaning medium must be saved, for recovery of the metals. Polishing of iron and steel can be effected in a dry barrel along with fine leather scrap.

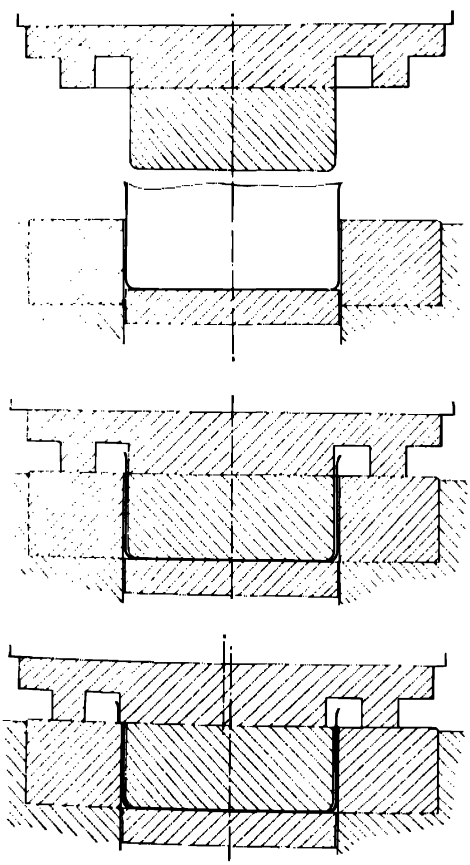


Fig. 77.—Trimming dies which operate by lateral motion.

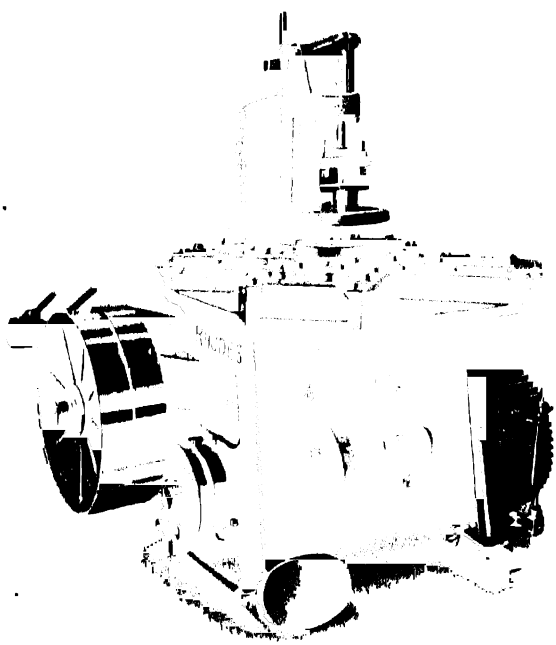


Fig 78.—High speed box trimmer of sliding-die type.

Barrels are made in various shapes, and some are closed, usually for horizontal running, while the open-ended types are set at an angle. The tilting arrangement is such that the barrel can be adjusted to the most suitable angle desired, and quickly lowered for emptying. The advantage of the open barrel is that the work may be examined at intervals without having to stop the rotation, and ingredients can be added similarly. Metal barrels are made in conical and polygonal shapes, and wood ones in round, hexagon, and decagon forms, hard maple or oak being the best wood to use, as it does not splinter, and has fine wearing qualities. Ordinary barrels measure from 16 to 28 inches diameter, but very small sizes are used by jewellers, silversmiths, and others, a hexagon barrel being mounted on each end of the spindle of a belt-driven head, each unit measuring about 9 inches long by 6 inches across the flats.

The speeds of barrels depend on the class of work, that of light character being run faster than heavy kinds; rates should not exceed 100 feet per minute for heavy objects, 150 for medium, and 200 for light pieces in a closed barrel. Speeds up to 300 feet per minute can be run, according to the sort of work, in the open-ended barrels.

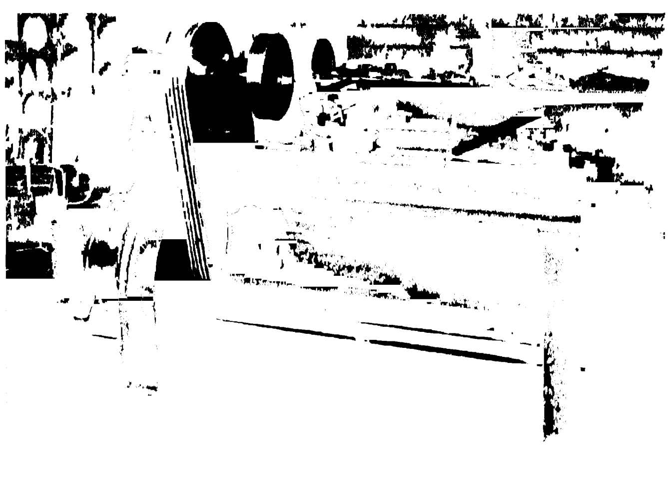


Fig. 79.—Trimming lathe provided with pedal control.

Rolling Mills.—In most cases sheet-metal works receive the material in the form of sheets, strips, foil, circles, and sections, and no rolling is done, but an exception occurs in the operation of mints, which include machinery for reducing the cast bars to size for stamping the coins. Gold, silver, and bronze fillets and strips are thus produced in a state of close accuracy. The rolls are short, and in view of the precision required high-class workmanship is essential, and fine settings have to be ensured in order to bring the strips to the close limits demanded. The speed of rolling varies according to the class of work, but an average is about 80 feet per minute surface speed. An example of the sequence in rolling may be quoted (on a Taylor & Challen mill), with the data as to successive reductions.

The strip is rolled from a bar $3\frac{1}{2}$ inches wide $\times$ $\frac{3}{8}$ inch thick, which has been annealed.

First	pass	reduces to	·3125 inch	Seventh	pass	reduces to	·12 inch
Second	,,	,, ,,	·25 ,,	(Anneal)			
(Anneal)				Eigth	,,	,, ,,	·08 ,,
Third	,,	,, ,,	·20 ,,	(Anneal)			
Fourth	,,	,, ,,	·16 ,,	Ninth	,,	,, ,,	·07 ,,
(Anneal)				(Anneal)			
Fifth	,,	,, ,,	·14 ,,	Tenth	,,	,, ,,	·06 ,,
Sixth	,,	,, ,,	·10 ,,				
(Anneal)							

The annealing is done at a dull red for bronze (about 1,000° F.) followed by quick cooling in water.

A breaking-down mill for gold, silver, or bronze bars is built with rolls of 12 or 14 inches diameter; in the first size the length is 14 inches, in the other 16 inches, and the revolutions per minute respectively are 47 and 40. A 20-h.p. motor drives the mill through spur and helical gearing. The rolls are made of chilled iron, turned, lapped, and polished, the top roll being suspended by bolts and balanced with volute springs. A handwheel, worm, and screw adjustment may be regulated to a scale reading to ·0005 inch. The rolls can be taken out without disturbing the housings. The feed and delivery table extensions are removable. The method of carrying the pinions is by a cast-iron box, bolted together in the centre, and holding the pinion lubricant, and bronze bearings are fitted in this box. A different mode of adjustment is to be observed in another design, which has a large wedge under each lower roll chock; a duplex bevel gear and screw mechanism alters the height, dials reading to one ten-thousandth of an inch. An adjusting arrangement in yet another example embodies the overhead method, but the twin screws are rotated by bevel gears from a graduated handwheel, thence a pinion turns spur wheels on the screws. One of the spur wheels has a slip adjustment by means of which, on loosening four nuts, the screw can be slightly re-volved to set the roll exactly parallel.

A spring balancing device is provided in some instances, so that the top roll and bearings do not drop between passes. Another special

arrangement consists of a water-cooling outfit whereby a current is sent through the rolls. Hardened-steel rolls are provided in many cases. A special-purpose light rolling mill having 12-inch rolls is designed for pinching and flattening copper strips previously twisted, at a speed of 150 feet per minute. The strip passes along a grooved guide; one roll is recessed, the other has a projecting collar.

A larger class of mill is utilised for breaking down and finishing the metal for cartridges and some other kinds of stampings. Slabs and ingots are thus reduced, from sections measuring 3 inches thick or less and about 21 inches wide. The rolls for this service range from 24 to 30 inches diameter, making 5 revolutions per minute, and the larger mills require 250 h.p. to drive.

Drag Benches.—Reverting to mint machinery, mention may be made of the drag bench, which is used for accurately sizing gold and silver strips after rolling. The drag head is fitted with stationary hardened and tempered steel cylinders, the space between which may be adjusted to one ten-thousandth of an inch. The drag jaws release automatically at the end of the stroke, which occurs at the rate of 300 inches per minute. A short portion of the end of the strip has to be flattened down before putting it into the machine, and this is effected on a flatting mill. The lower roll has three flats, which allow the end of the strip to enter between the rolls. As the rolls revolve continuously the strip returns towards the operator, the end being rolled down between the circular parts of the rolls. A grease mill is another adjunct, having a pair of metal rollers, and a pair of felt rollers saturated with oil from a box. Both sides of the strip are thus greased before the strip goes to the drag bench.

CHAPTER 4

MACHINES FOR MISCELLANEOUS OPERATIONS

THERE are a number of what may be termed minor operations in the sheet-metal industry which can be performed by machines of a simple character often operated by hand, although if the production requirements demand it, they may be of the more complex automatic type. Some of these machines perform only one process on the metal, while others will do combined operations, which avoid the necessity for separate handlings of the piece between each process. When automatic machines are run in connection with presses, the capabilities of the former must of necessity be equal to those of the latter, so that there is thus continuous production according to schedule. Many of these minor operations are performed by rotary action in the machine. Some of these machines may now be briefly examined.

Indenting Machine.—Indenting or scoring is the name applied to the treatment given to the tear-off strips of tins, such as those for corned beef, enabling them to be easily opened. Straight or curved scoring can be produced, the body blanks being passed over a table having a guide strip which controls the movement, and the machine is so designed that the disks can be readily changed as required. Indenting of another class is performed on the ends of certain articles, for example, cartridge cases, in order to make a recess on the surface of the metal, this being done by means of a die.

Screwing Machines.—The rolling process, which is sometimes employed in the production of threads to be formed on certain classes of solid screws and bolts, is the method practised for indenting the screw thread on sheet-metal articles such as caps, lids, sockets, necks, nozzles, burners, etc. In the simple hand-driven machines, the chuck or screwed former is turned by means of a hand wheel on the spindle, and the threading spindle is fed up by a lever. This type of machine will deal with diameters from $\frac{3}{8}$ inch to $1\frac{1}{4}$ inches, and is secured on the bench. Another bench style, working up to 4 inches diameter, has a belt-driven spindle, with a treadle motion for the feed. More rapid action and more uniform pressures are obtained in the automatic machines, which will screw about fifty pieces per minute, from $\frac{1}{2}$ inch to 5 inches diameter, and 3 inches in length. A larger model, which possesses automatic movements, is shown in Fig. 80, and functions in the following manner. The article is placed on the screw chuck, and the treadle depressed, with the result that the

adjustable clamping tailstock comes up, and the clutch is engaged, the degree of pressure being automatically controlled, thus ensuring uniform threads of correct form. The ratios are obtained from change-speed gears, and a chart is provided to show the correct combinations for different-sized objects. The specification is:

Range of sizes	$\frac{7}{8}$ inch to 5 inches
Maximum length of work accommodated	18 inches
Average production per hour	1,000
Number of ratios of change-speed gears for the complete range	6
Power required	3 to 5 h.p.

Larger sizes of machines are those which screw the necks and caps of steel drums, admitting drum heads up to 18 inches diameter, and screwing

Fig. 80.—Semi-automatic thread-rolling machine. (Hordern, Mason & Edwards, Ltd.)

caps up to 8 inches diameter, the machines being hand controlled. The Taylor & Challen machine for rolling the threads on to the lids of drums, which is shown in Fig. 81, has an output of twenty per minute, the minimum diameter being $8\frac{1}{2}$ inches and the maximum $10\frac{1}{2}$ inches. After the lid has been placed on the revolving die, depressing the pedal seen on the right causes the floating die to slide across until it is in line with the screw threads, then the pedal on the left is depressed, which brings the clutch into operation. The back shaft then rotates, and a cam throws over the floating die and keeps the pressure applied until the threads are rolled.

Combination Machines.—An interesting class of combination machine is that dealing with two or more processes in which thread rolling is included, the combinations comprising: beading and thread rolling;

knurling and thread rolling; knurling, thread rolling, and curling. Combination machines which do not include threading are: beading and trimming; curling and knurling; beading, recessing, and curling; beading and curling; curling, knurling, and indenting. Both automatic and hand-fed machines are constructed for these services, outputs as high as 6,000 pieces per hour being obtainable on some of the former types. The articles are placed in a chute, from which they roll down to the tools, these being easily changed for the different sizes and shapes. To obtain extremely accurate threads a screwing-off device is fitted, which ensures that the threads shall be exactly to gauge. Fig. 82 is of a triple-operation type.

Rolling Threads on Screws.—Many of the small screws used to fasten sheet-metal articles together are also rolled, this being a quicker and cheaper method than screwing by dies. As the act of rolling makes a screw that is larger in diameter than the wire from which it is produced, this effect has to be countered by the correct selection of the blank diameter. When the thread is rolled, since the surface metal cannot be compressed into the central portions, it has to be forced up to form the vee of the thread, so that when the shank has to be of the same diameter as the threads, the blank must be shouldered and reduced along the length to be threaded.

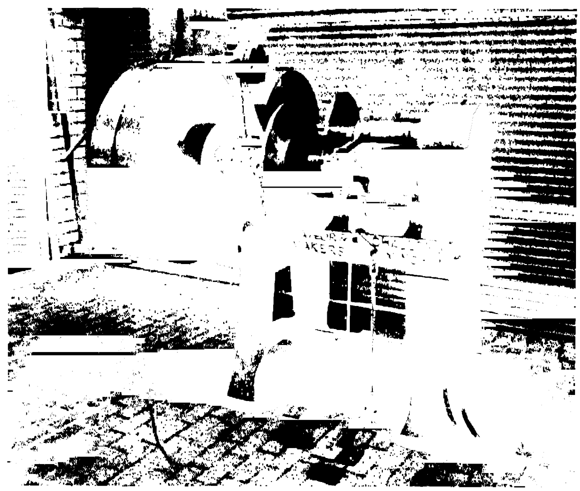


Fig. 81.—Thread-rolling machine for drum lids.

Flat dies are employed, having a series of parallel thread sections set at a definite angle, these being arranged above and below the blank, and accurately set. The movement of the wire is controlled so that the grooves produced by one die will exactly meet those produced by the other when the wire has made a half revolution. The dies are cut with a hob having a face wide enough to cut the entire surface of the die at one setting, the threads having no lead, as have those of ordinary threading hobs, but the thread sections are parallel with the ends.

The method of procedure for finding the diameter of wire and angle of threads on the dies is as follows: Assuming that it is desired to make dies for a standard $\frac{1}{4}$-inch screw with twenty threads to the inch, right-hand, it is necessary to ascertain the diameter of blank requisite to make such a screw, and from this determine the angle of grooves in the dies. To find the size of wire, first measure the pitch of the screw; this would be $\frac{1}{20}$ or ·05 of an inch, and having determined this, subtract from the

diameter of the finished screw the product of the pitch, multiplied by one of the following factors, which will vary according to the diameter of the screw :

If the screw is smaller than $\frac{1}{8}$ inch	·55
From $\frac{1}{8}$ to $\frac{3}{16}$ inch	·60
From $\frac{3}{16}$ to $\frac{1}{4}$ inch	·65
From $\frac{1}{4}$ inch and over	·70

Therefore, for the $\frac{1}{4}$-inch diameter screw under consideration, the pitch ·05 multiplied by ·070 equals ·035, and the diameter of the screw, ·25 less ·035 equals ·215, which is the exact diameter of the wire required.

Fig. 82.—Automatic threading, trimming, and beading machine. (A. C. Wickman, Ltd.).

To find the angle of the grooves on the dies, find the circumference of the wire to be used, and note how many times it is contained in 1 foot, thus, diameter multiplied by 3·14 equals ·675, this being the circumference, and 12 inches divided by ·675 equals 17·77 ; in other words, the wire would have to be revolved about $17\frac{3}{4}$ times to equal the length of 1 foot. As at each revolution the incline of thread would be ·05 in $17\frac{3}{4}$ revolutions, the incline would be $17\frac{3}{4}$ multiplied by ·05, or ·88. This would therefore represent the incline per foot at which the dies would have to be set on the milling machine.

Rotary Swaging Machines.—A different system of reducing or tapering from that produced by dies is much employed in the rotary swaging machines. The sheet-metal tube (or the machine can be used for swaging a rod) is passed through a spindle which has hardened rollers running at high speeed, and these hammer the work by a number of

light blows into the form desired. The action is gentle but positively formative, giving a fine, smooth finish, while the metal becomes consolidated and made tougher and stronger.

Closing Machines.—The operation of pressing the lids or the ends such as are used in the production of certain kinds of receptacles often calls for the use of machines that facilitate this work, as, for example, if the lids are secured after the receptacle has been filled. For small tins and canisters there are both hand-manipulated and automatic machines designed to do this job. The former type consists of a round pillar on a bench stand ; at the lower part of the pillar a table is clamped at a suitable height, and above this is a bracket through which a spindle is slid by a lever. After the tin has been filled with paint, treacle, etc., it is placed on the machine, and the spindle carries a closing disk which descends on the lid and closes it over. The automatic type of lidding machine deals with about 100 canisters per minute. These arrive at the machine on a travelling conveyor band in single file, while round lids are placed loosely in a hopper, from which they are automatically released and pressed on to the bodies. Lids which are not round must be fed into the delivery chute by hand.

A heavy class of machine has been designed for pressing the tops and bottoms into the bodies of 40-gallon drums previous to the flanging and seaming operation. A horizontal bed supports right- and left-hand headstocks, each holding a chuck on a slidable spindle. The tops and bottoms are put on these chucks, and the body is rolled in on to a cradle between the chucks. When a pedal is depressed, two top and bottom jaws close round the edges of the body, to give it a perfect circular shape, and, while it is thus held, the two chucks move forward and force the tops and bottoms into the body.

Cartridge Machinery.—A number of special machines are utilised in plant designed specially for cartridge manufacture, and a brief review of these may be of interest. The operations involved concern both the production of the cases and the bullets. In the initial stages, certain presses, of types which have already been described, are employed, but several special kinds of machines are required which have no place in other branches of sheet-metal work. The first process performed on the sheet metal in the production of the cases consists in cutting and cupping, this being effected in rather powerful open-fronted or double-sided presses provided with feed rolls, the leading ones having a pad which cleans the strip ; scrap shears are also fitted. Among the differences between these special machines and the more normal types are that the press stands in a suds tray, and that, in many instances, multiple tools are arranged (Fig. 83), both for making cases and bullet envelopes. One of the latter kind of presses operates four tools, and at 300 working strokes per minute the output in that time is 1,200 cups. Each respective set of tools on one machine has its separate feed chute, in order to enable the attendant to examine the individual working of each set of tools.

Fig. 83.—Cutting and cupping press, using multiple tools.

Fig. 84.—Hopper-feed press for first drawing operation on cartridge cases. (Taylor & Challen, Ltd.)

Drawing and extending are performed in several stages, with intermediate annealings. On some machines, feeding is by turntable, horizontal presses using chute feed, but the large cases must be hand-placed. The combination of dial and hopper feed occurs in some instances, the units from the hopper automatically coming down into the holes in the dial, the hopper being so designed that it cannot over-feed. A different combination is employed on a machine that passes the cups from the hopper on to a revolving plate, on the periphery of which slots are cut

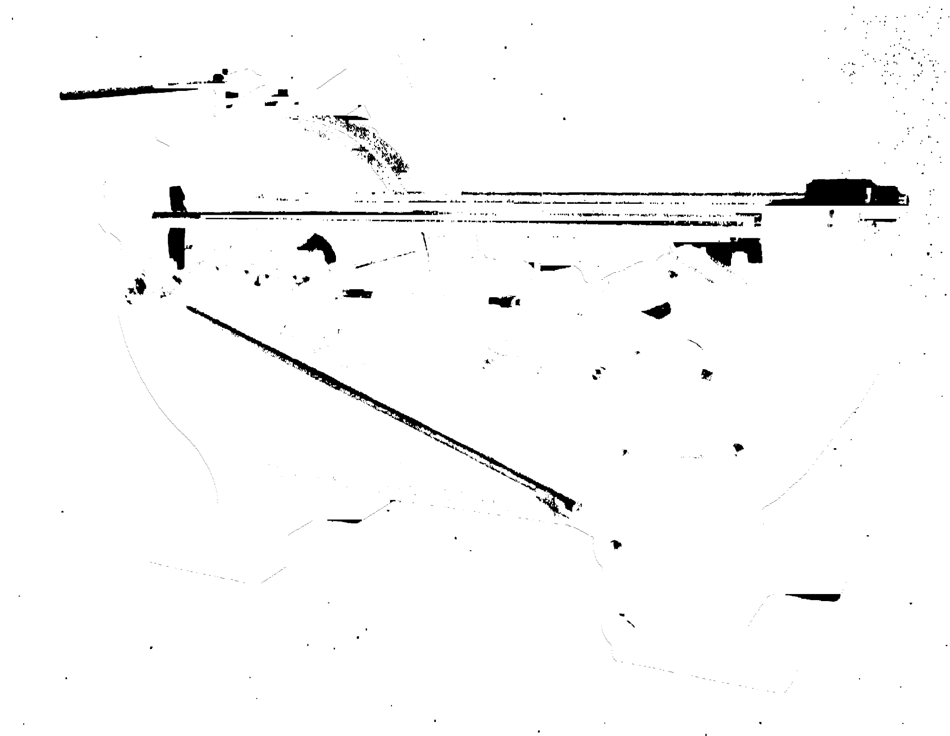


Fig. 85.—Cartridge-case indenting press.

to the correct form of the cups. The latter, falling into the slots, are taken around and dropped down a chute, whence they are carried to the die by a pusher (Fig. 84).

After the indenting process, which is done in a horizontal press (Fig. 85), the cases are taken to a tapering press (Fig. 86), where they are transferred by an automatic pecker feed to the dies and tapered, the head is then rectified, and the pushed cases are ejected at a speed of about sixty-five per minute. An additional attachment may be included which rectifies the mouth before the dies are reached, dented or elliptical mouths being thus trued to a circle.

The heavy work of heading demands the use of very strong horizontal

Fig. 86.—Cartridge case tapering press.

Fig. 87.—Heading press for cartridge cases.

presses of the closed-frame type (Fig. 87), in order to eliminate all risk of springing, the heading slide and the extractor slide being actuated by toggle mechanism from the crankshaft. From fifty to ninety strokes per minute are made in the various machines of this type, and from 3 to 5 h.p. is required for driving the different presses.

After successive drawing operations, which are followed by a trimming process, bullet envelopes are "formed" in three stages in a horizontal type of press, equipped with chute feed. The parallel-drawn envelopes roll down to a slide, where they are taken separately under a pair of fingers, which places them in front of the die, the extractor entering at the back of this die and pushing out the formed envelope, whence it falls into a box, the rate being about seventy envelopes per minute.

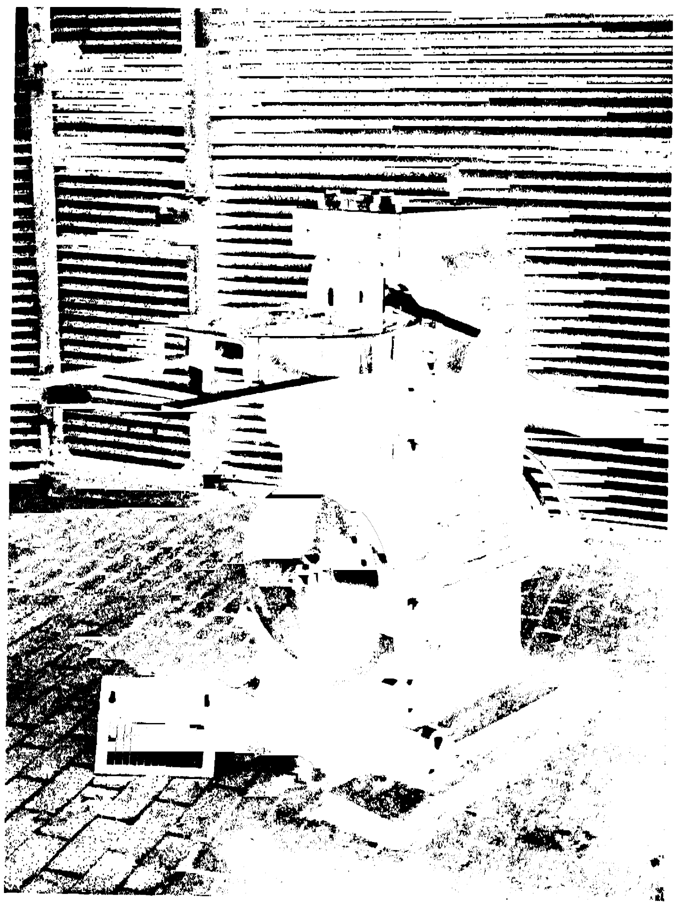


Fig. 88.—Bullet-pressing machine having a turntable and three sets of tools.

Bullet-pressing Machine.—A special turntable design of press is used having three sets of tools, the process being as follows: the bullet envelopes, complete with aluminium tips and lead cores, are fed on to a turntable, and this carries them around between the three sets of tools which are fixed in an overhanging head. As the table slide rises the first set of tools forces the aluminium tips and lead cores into the envelopes, the second turns over the envelopes, and the third extracts them, so that they fall away down a chute. The top tools are adjusted by screws and nuts, and there are thirty stations, the number of strokes per minute being 100 (see Fig. 88).

Frazing and Reamering.—Frazing, or trimming to length, and mouth reamering require the service of a horizontal dial-feed machine, which

for the size under consideration works at the rate of 140 cases per minute. The frazing and reaming spindles run at 2,500 revolutions per minute, and a ten-hole dial is employed which moves one-fifth of a turn per cycle of events, so that the operations are done in duplicate. The sequence on these five pairs of centres is: (1) the cases are pushed from two chutes into the dial; (2) they are frazed and reamed; (3) cleaned by brushes; (4) gauged to length; and (5) ejected.

Turning and Reaming.—An automatic hopper-feed machine is responsible for the head turning, trimming to length, and mouth reaming, the cases being separated from the swarf after ejection, the rate of output being thirty-five per minute.

Firehole Piercing or Drilling.—The fireholes may be either punched or drilled, special machines being available for both processes. In a combined piercing and marking machine of the vertical double-standard pattern, a crankshaft lies at the bottom of the framing and moves a slide lying below a turntable into the holes of which the cases are placed, mouth downward. The dies carried on the slide enter from underneath and lift them slightly against the punches, the marking dies being in a fixed holder in the head of the press.

In two designs of machine where drilling is employed one has chute feed and the other turntable feed, the production rate being about fifty per minute. The drills have a speed of rotation up to 11,000 revolutions per minute.

Marking Machines.—For the purpose of marking the heads only, a hopper-fed machine is built to work automatically, the punch approaching horizontally, while in another design a vertical press is employed which rectifies the cap chambers and letters the heads, double-crank drive being fitted to ensure even pressure, and a turntable transfers the cases underneath the punches. A final handling is necessary for the process of gauging; the cases fall down a chute at the speed of seventy a minute, wherever they are passed through the gauges, the rejected cases falling in a different direction from the true ones, which go into a box.

Capping Machines.—Both vertical and horizontal types of machines are employed to fix the caps in the cases. The vertical press has a turntable feed, and handles either empty or loaded cases. For the latter, firing tubes are provided under the punch centres as a safeguard against accidental explosion, the capped cases being ejected automatically. A combination of hand-placing of the cases in the feed wheel, and automatic supply of the caps from a hopper, occurs in the horizontal machine. At each revolution a cap is brought opposite a case and in line with the punch, which advances and pushes it into the chamber, the primed case being carried on and extracted.

Tin-foiling Machine.—A small multiple-die press carries a sliding plate containing caps in the numerous holes, and at each stroke nine disks

are cut out and inserted in the caps, the tinfoil being fed so as to leave the minimum quantity of scrap.

Canneluring Machine.—The function of this machine is to roll the grooves in the bullets. A table is provided with a spindle projecting above it, the latter carrying the revolving disk which impresses the grooves in the metal (Fig. 89). There is a steel segment on the table at one side of the disk, and a thrust block at the other side to prevent the side pressure from affecting the spindle, the bullets being fed down a tube, pushed forward automatically, and rolled between the disk and segment. The various other types of machines which are utilised in a cartridge plant hardly come within the scope of a treatise on sheet-metal work.

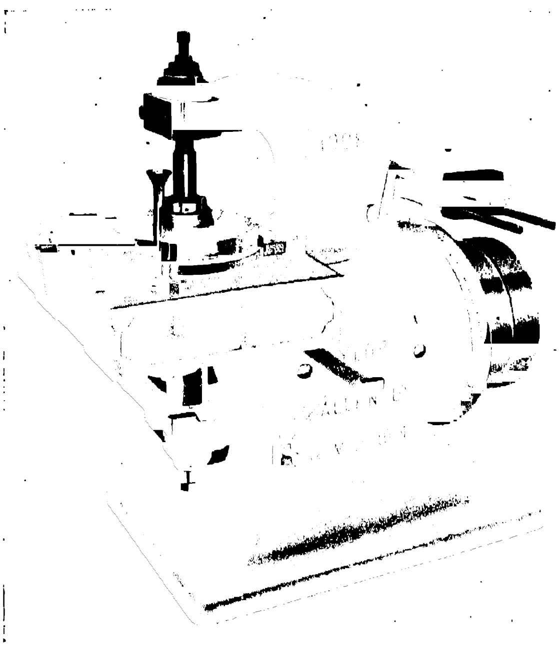


Fig. 89.—Canneluring machine which rolls the grooves in bullets.

Marking Machines.—As distinct from the machines described above for cartridge-case heads, hand- and oil-operated marking machines are available for general service, to impress names, figures, trade marks, and lettering on flat or round metal articles. The principle employed in both classes of work is to have a vertically elevated table to carry the work, and an overhead slide which propels the die across. For flat surfaces a round die is used, and for round surfaces a flat die, so as to roll the impressions in. The slide is moved across by a hand lever, and the table raised by a pedal to put on the pressure, an adjustable stop regulating the height of movement. In the hydraulically operated machine the power enables it to mark up to ten lines of $\frac{1}{8}$-inch letters, to a maximum length of 7 inches. The oil pressure is maintained by a small rotary gear pump, and on depressing the pedal the power is used automatically to elevate the table to the required height and to feed the die across, the table then dropping and the dies returning to their original positions. If the pedal is kept down, operation becomes continuous, but the speed of travel of the die and the pressure of the table may be varied by means of valves.

Engraving Machines.—Engraving machines (Figs. 90, 91) are employed to cut figures, letters, designs, etc., on any sort of metal articles by a milling

process, the pantograph principle being usually embodied to give the necessary reproduction from the original copy. The simple cutters are ground on their ends to a suitable shape to produce straight or bevelled sides, or flat-bottomed cuts when these are required to be filled in with paint or other substances. The cutter spindle is driven by a cord which runs over guide pulleys in such a manner that the extreme movements of the cutter head over the work are accommodated. The piece is clamped to a T-slotted table, and the pantograph frame is pivoted to an arm on the top of the column. The copy-holder is fastened on a table at the tail end of the arm, and a pointed style at the tip of the panto-

Fig. 90. Pantograph machine cutting out shapes, under control of a celluloid master copy (Taylor, Taylor & Hobson, Ltd., Leicester.)

graph lever is caused to follow the copy, the cutter being lowered into the cut by a feed screw. The pantograph can be altered, to graduations, to make the engraving to any proportion between one-third and one-sixteenth that of the copy.

The copy is either cut specially, when this becomes necessary, or for standard letters and figures sets are supplied and clamped in rectangular frames or circular dials, the latter having the letters engraved in a circular formation.

Profile Grinding Machine.—A different application of the pantograph principle is seen in the profile grinding machine, which is of interest in sheet-metal working of the highest class of accuracy, since it is used in

the production of templets, profile gauges, and various types of forming tools. In this case an engraved copy is not used, but a drawing is prepared to a very large scale, perhaps as much as 50 : 1, this being drawn with a hard steel pin with the very thinnest possible lines, because any deviation in the following of the lines by the steel tracer-pin will result in an appreciable error. The drawing is laid on a board, and as an assistant follows the lines on the drawing, the person actually performing the grinding operation observes the path of cross lines in the field of a

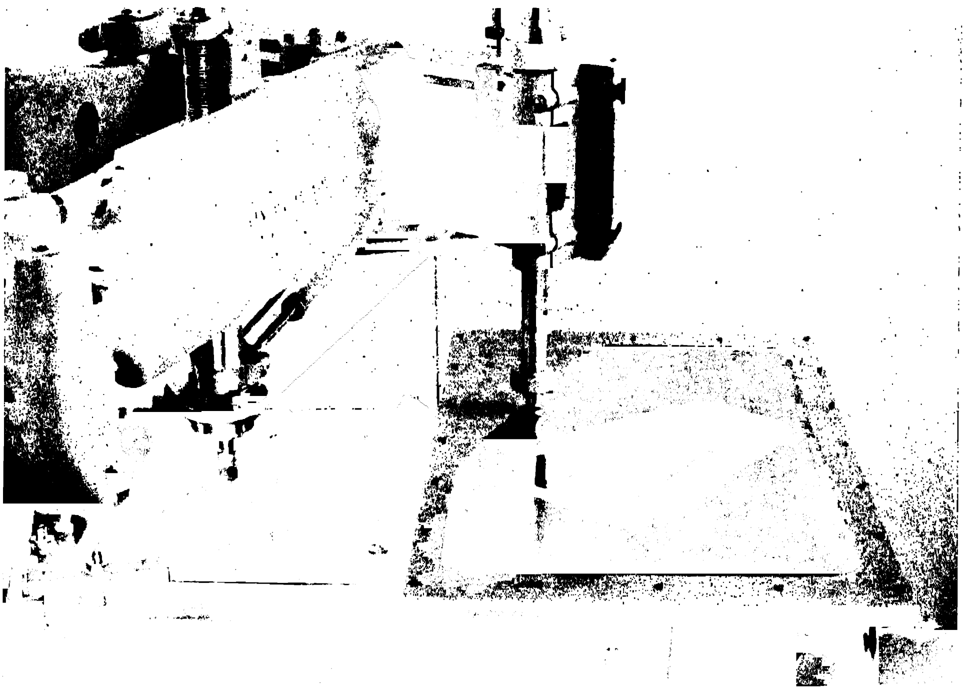


Fig. 91.—Grinding out a die on the pantograph machine, to produce the shape seen lying on the copy. (Taylor, Taylor & Hobson, Ltd.)

microscope which is moved by the pantograph. He then feeds the work-holding table so that the piece is traversed towards the grinding wheel, and sufficient ground away until the cross lines, which have a circle at the centre, coincide with the edge ground. The process is continued until the whole length of the profile has been reproduced, the cross of the microscope travelling point for point along the profile to be ground. The grinding wheels are selected of a profile suitable to the shape, as it is necessary to use a straight-faced wheel for some outlines, single or double bevels, or rounded edge for others. Dressing devices are employed to obtain the correct angles or radii. In the first case, a diamond holder is fed angularly by a slide which can be set, by graduations, to the inclination desired, in the other a rocking movement is imparted to move the diamond in a radial path.

Bench Profile Grinder.—A simpler class of machine, without the pantograph mechanism, is built for finishing dies, templets, gauges, and experimental or other sheet-metal parts to a precision degree, on outside or inside contours. The work is hand controlled, manipulating it to scribed lines or a templet, and the grinding wheel or roller projects vertically from a circular table. Pieces can be finished quickly and accurately, instead of filing or stoning, and angles of clearance may be accurately adhered to. The machine is enclosed in a cast-aluminium housing, containing a motor running at 3,450 r.p.m. and belted to the grinding spindle, which makes 20,000 r.p.m. The spindle also has a reciprocating motion, for the purpose of increasing the rate of cutting, preventing uneven wear on the wheel, and improving the finish. The table can be raised or lowered to the extent of $1\frac{1}{4}$ inches, and embodies a tilting adjustment that can be set accurately by a sine bar, giving angular settings up to 5 degrees, at different table heights. All the working parts are below the table, so that the work is always plainly visible, and as the machine is easily portable it may be placed anywhere as convenient. The diamond dresser clamps to the tee slot in the table, and is made with a swivel joint for setting. The weight of the outfit is 85 lb., and the table is 10 inches diameter. A $\frac{1}{4}$-h.p. motor does the driving. Wheel diameters are $\frac{3}{16}$, $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, and $\frac{3}{4}$ inches, in lengths of $\frac{1}{2}$, $\frac{3}{4}$, 1, and $1\frac{1}{4}$ inches.

The alternative to some such special machine is to employ a jig saw with attachment to carry oilstones by means of which thin pieces or dies may be trued up smoothly and accurately, either at right angles, or with draft, by tilting the table. A range of oilstones can be purchased for this purpose, in round, square, and triangular sections. Preparatory filing may have to be done in many cases after the sawing out has been effected, but the stoning method is, of course, the only way when dealing with hardened pieces.

CHAPTER 5

DIES USED IN PRESSES

DIES are used so extensively in modern practice for the production of such a great variety of sheet-metal parts, that a study of their design and manufacture becomes a subject of great importance to anyone at present associated with engineering production methods, or others contemplating it. In the foregoing chapters the construction and design of a few of the ever-increasing forms of press tool in use in the factory has been dealt with. In the design of dies and the methods employed in their fabrication, future procedure must be, to a great extent, governed by past experience or upon a knowledge of those methods of production which have already proved satisfactory. Experimenting is a very costly affair, so that the present or future designer or maker of tools can often avoid useless work by studying the practical knowledge underlying the design of existing types, especially when such knowledge has already been tested in commercial production. This information is here given in a brief and concise manner, and the principle underlying a good many tools and dies are explained which actually do the job at the present day.

The many and varied types of die used in a power press for the fabrication of sheet-metal parts can be divided into a very few classes, although a great deal of variety may be found among the units which constitute a general group. In the first class may be placed those dies which cut, crop, shear, or blank flat pieces from the material as a primary process to the manufacture. In the next class are those dies which change the form and shape, either by forming, drawing, bending, etc., from the original flat sheet, these being termed blanking dies. In the remaining classes are those dies used for bending, forming, and drawing, which incorporate two or more operations, but in which definite classification is uncertain. Those which are the most usual for general or standard uses are piercing and blanking dies in which, as the name implies, the action is to pierce holes in the part to be produced, also to cut or blank the piece out to the required shape ; blanking and forming dies ; which sever the piece from the flat and form it to the predetermined shape in two or more continuous operations ; blanking and bending dies ; in which the name definitely implies their function, and blanking and drawing dies ; which also could not be misinterpreted. These include the main standardised production tools, but there are also the smaller types such as "follow dies," which imply a sequence of operations " following on " in continuation and producing the complete part. With piercing dies, cropping dies, swaging

dies, embossing dies, coining dies, the name explains exactly the job of work which they are expected to do, while staking dies are employed to fix one part on to another by various methods.

The term " die " in the trade usually means the complete tool, but, on the other hand, it can be confined to the female or lower member as distinguishing it from the punch, which is often called the " top tool," which position it mostly occupies, although this is not invariably the case. A punch is that part of a press tool which enters into a hole, recess, or opening in the die member. It is possible for a complete tool to be so constructed that one component acts the dual parts of both punch and die, as in a compound tool (see Figs. 109 to 112, pp. 107 to 109); on the other hand, the punch can occupy the lower position if the tool is designed inverted. Should it be that the upper and lower forces perform an identical action, as in an embossing tool, then usually the top or moving member would be called the punch and the other the die. The terms " double-action " die, " triple-action " die, and " multiple-action " die are very misleading, as this signifies the type of press in which the tool is to be used, as for example a " triple-action " tool, in a single-action press, could not perform the required number of operations; on the other hand, a single-action tool may perform quite a number of functions, for example, the number which will produce the complete article called for.

Blanking Dies.—The ordinary blanking die is among the simplest forms of press tool, and its function is to cut out plain pieces of flat material with a definite shape profile. This type of tool is made up of a die, which can be constructed of one or several parts, with an opening which conforms to the shape of the part to be produced or blanked out. The punch, which is in form and size exactly the same as the die opening excepting for certain allowances, termed " die clearances," which will be explained later. The tool, when operated by a press, cuts or punches a piece, which will be a facsimile of the die opening, from the material placed between the punch and the die. It often happens that the stock to be blanked is so thin that it has a tendency to be driven down between the upper and lower members of the tool concerned, tearing instead of cutting. The area of die opening also having a great effect, the designer must consider this in his calculations, and instruct the die makers to form a " shear " on the die face, by making it lower in the middle than at either end, to reproduce the action as in a pair of scissors (Fig. 92).

Shear on Punch.—This method is only adopted when not the blank but that part of the stock surrounding it is required, and it can be easily visualised that the material resting on the flat surface will remain flat, while that resting on the modulated face will become distorted (Fig. 93).

Stripper Plate.—This part of the tool is to strip the material from the punch which it passes through. In some instances it is made a " snug " slide fit on the punch, which will then act as a guide when the tool is working, but on the other hand, when the tool is of the pillar type, which

will be explained later, this is unnecessary, and the stripper can be a slack fit, the pillars maintaining the alignment of the punch and die.

Between the stripper plate and the die face there are placed strips of mild steel, termed "stock guides," which form a channel or road for the material to pass along, keeping it in a position fairly equally distributed over the die opening. This opening is arranged that the stock can slide through with ease, as there is sometimes expansion when the punch pierces it. Often this channel is formed by a groove being machined in the underside of the stripper plate, in depth equal to the height of the stop, plus the thickness of material being cut up, plus the clearance, which should be considerable in case the strip distorts when struck by the punch. In a tool of this type, the spacing of the holes is determined by stops as already explained. It often happens that the shape of the piece to be punched out is of such form that if a consecutive run is made it would be wasteful of material; in this case the tool is so designed to make a run, missing every alternate blank, the stock strip being then turned round and run through the other way, or two punches set the reverse way to each other may be employed, which answers the same purpose, although with twin or gang punches they are not always placed side by side

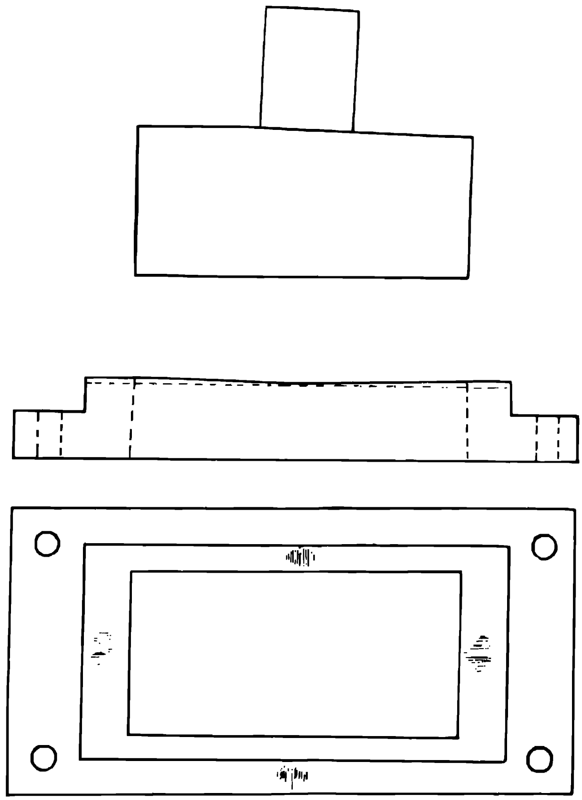


Fig. 92.—Showing die constructed with a shear.

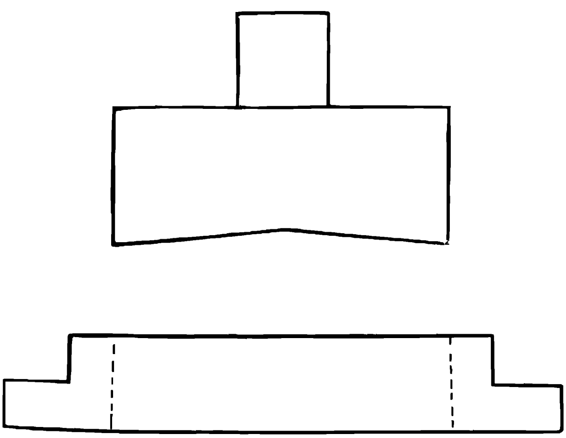


Fig. 93.—Showing punch constructed with a shear.

in the position in which they will eventually appear on the strip, as the wall between the two or more die openings might be too thin, and would probably break away (Fig. 94).

Before making the die of a blanking tool, it is necessary to discover what size of flat blank will be required in order to form the component when it is bent or drawn up. If it were possible to form or bend metal without thinning, stretching, or ironing, the development would be simplified, as it could be determined with a great degree of accuracy by calculating the area of the finished part, and making the area of the blank to correspond. In some cases there is only a small amount of stretch and ironing, especially if the fabrication can be drawn or formed in one operation, but where several operations are necessary to produce the required shape, there is much thinning of the metal and the blank will have to be considerably smaller in relation to the finished size. It is also obvious that the class of metal to be shaped will play an important part ; should it be of a soft nature, such as aluminium or copper, the amount of stretching will be greater than if the article is composed of a metal like hard brass or stainless steel.

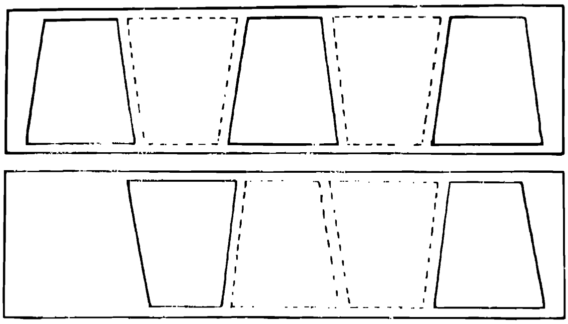


Fig. 94. Two methods of blanking strip.

The pressures required for blanking or shearing are very difficult to determine, as the temper of the metal concerned will have a considerable effect. The following table, based on the shearing strength of mild steel, 50,000 lb. per square inch, carbon steel, 75,000 lb. per square inch,

No. of Gauge. American Standard, Brown and Sharp.	Punching, in lb. 1-inch Diameter Hole.			Shearing, in lb. 1-inch length.		
	Mild Steel.	Carbon Steel.	Brass.	Mild Steel.	Carbon Steel.	Brass.
20 ·031 inch	5,800	8,835	4,123	1,875	2,812	1,312
18 ·040 ,,	7,854	11,781	5,498	2,500	3,750	1,750
16 ·050 ,,	9,817	14,726	6,872	3,125	4,687	2,187
13 ·071 ,,	14,765	22,148	10,335	4,700	7,050	3,295
11 ·090 ,,	19,635	29,452	13,744	6,250	9,375	4,375
$\frac{3}{16}$ inch	29,452	44,178	20,616	9,375	14,062	6,562
$\frac{1}{4}$,,	39,270	58,905	27,489	12,500	18,750	8,750
$\frac{5}{16}$,,	49,087	73,631	34,361	15,625	23,437	10,935
$\frac{3}{8}$,,	58,905	88,357	41,233	18,750	28,125	13,125
$\frac{1}{2}$,,	78,540	117,810	54,978	25,000	37,500	17,500
$\frac{3}{4}$,,	117,810	176,715	82,467	37,500	56,250	26,250
1 ,,	157,081	235,620	109,956	50,000	75,000	35,000

These figures are for a die and punch without shear.

and brass, 35,000 lb. per square inch, may be of interest, but the values given are, of course, only approximate.

Stripping.—No set rule can be used to much advantage in estimating the amount of spring pressure needed for stripping when designing a press tool.

Experience of tool-making, both in this country and abroad, has shown the writer that the potential value of springs is always over-rated by the novice and the amateur, and it is desirable to avoid this failing. Springs are very valuable in the construction of some drawing and forming tools, for lessening the abrupt shock of the blow when the press is operated, but it should be recognised that the amount of spring pressure needed to push a component out of a die depends on various factors, such as the gauge of material being used, the thickness of the metal conforming to that for which the tool was designed, and the shape of the component being stripped. Thus, if a tool were designed and made to strip material ·032 in thickness and the stock happened to be ·036, in all probability it would stick or there would be difficulty in pushing it off. The amount of power needed to strip the metal from a punch which it has passed through is governed by area, and also the thickness of the metal or other substance being cut up. As a practical example of this, if it takes 100 lb. pressure to strip material ·032 inch thickness from a punch 1 inch in diameter, then it will require 200 lb. to strip the same material from a punch twice the size. On the other hand, if the thickness of the material being pierced is increased from ·032 inch to ·064 inch, exactly the same proportional increase in power needed would apply. Furthermore, should the blank being struck have any large piercing previously, it will require very little effort to force it out of the die, as when it is struck by the blanking punch it will have a tendency to collapse on the hole, which in some tools causes a great deal of trouble, as will be explained later.

Medium-size Blanking Tools.—The process of manufacture differs with different sizes of tools, again tending to show that no set rule can be adhered to. A few years ago, very few tool-makers agreed as to method of procedure, many being convinced that the punch should be made first, whilst others were equally certain that the die should have precedence. The writer, having studied the question quite deeply, has come to the conclusion that the simplest way is to make the punch and then make a die to conform to it, although by this method the blank produced can very seldom be guaranteed to size to within a few thousandths. Should it be necessary that the blank produced must conform to a definite size, known in the tool-room as "spot on," or to come within a tolerance error of ·002 inch, then the die requires to be made first.

A definite line should be pursued with regard to the making-up of a good-class blanking tool, and if it is done in the stages which many years of experience have shown to be correct, not much can go wrong ; but without a system anything may happen.

The making of an ordinary medium-size blanking tool in an ordinary

shop may be first considered, and it is assumed that as there are no expensive and elaborate machines such as are on the market to-day, the tool-maker's knowledge, craftsmanship, and initiative will be relied upon to carry the job through. The drawing, if one is available, should first be studied and the form marked out on metal—a piece of brass or steel—as a template. The necessity of checking over the dimensions several times may be stressed in order to be quite sure that the template is really correct, as, to discover that something is wrong when half-way through the making of the die is a catastrophe indeed. In several small shops the template is checked over by an inspector before the tool-maker proceeds.

Assuming now that the template is correct, a piece of steel is prepared for the die and a piece of mild steel for the stripper plate, both being of about the same size, although the die is usually the thicker of the two. Hot-rolled or "black" mild steel is the best to use, as cold-rolled or bright mild steel (which is the same thing) retains the stress imposed by the rolling and when the centre piece is cut out it is liable to distort. Should it be necessary to use cold-rolled steel, then it must first be annealed by heating it up to a dull red heat—700° C. (approx.)—and allowed to cool off. These two plates are then screwed together, after having the faces ground, if this is possible. Four screws and four dowels are usually employed, and they should be so arranged as to pass through the stock-guide strips and not interfere with the die opening (Fig. 95). A corner of each plate is usually marked with the centre punch to facilitate assembly and the two plates are taken apart.

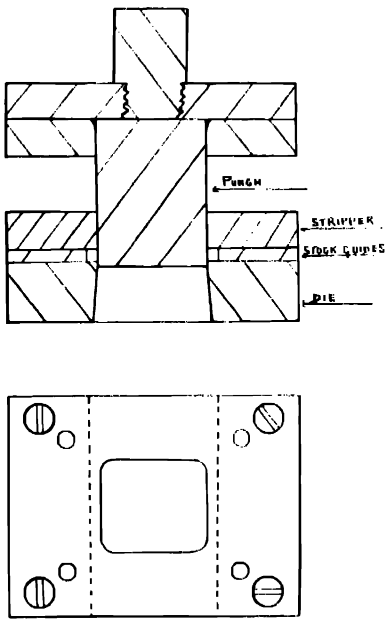


Fig. 95.—Example of a small blanking tool.

It now behoves the tool-maker to concentrate on the die, as this is the all-important part. The face is washed over with sulphate of copper (or "bluestone") and the die marked out, preferably with the height gauge. The cutting-out process before the advent of the band saw was always accomplished by drilling a series of holes as close up to the profile line as possible, but that part of the profile which followed any radii was always drilled and reamered to size. The question may be asked, "How is it possible to get the various radii to size if they do not conform to standard?" The method employed for this by the experienced mechanic is quite simple. He chooses drills as near to the radius size as possible but a little smaller and then employs tapered reamers, which he uses from the back of the die, until the exact size is gained at the face, at

the same time producing a definite angle for the die draught or backing off, which can be followed right round the die opening (Fig. 96).

Ordinary taper reamers are not quite so difficult to make as an amateur might consider. Silver steel or any form of low-grade carbon steel is chosen of the nearest size to the larger end of the reamer needed; it is then turned to the required taper, which, in this case, would be $\frac{1}{2}^{\circ}$. Six fairly equal sides are filed to form six edges and a square is made at the top end to fit a wrench. The reamer is then hardened and tempered. When these holes have been made to satisfaction, the remaining holes are drilled to remove the centre, which will eventually form the die opening.

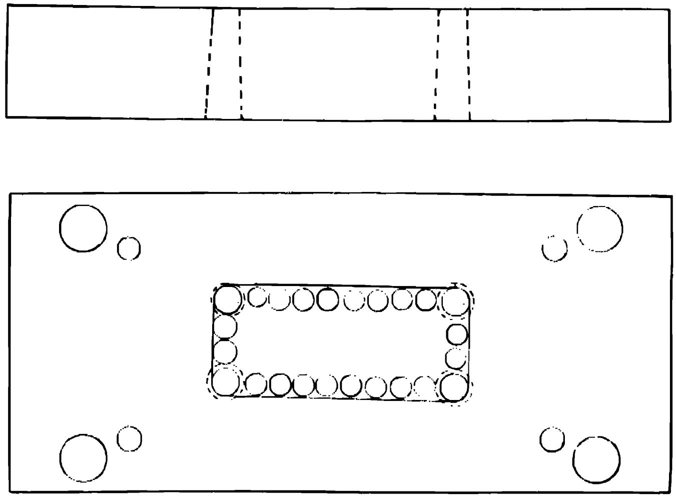


Fig. 96.—A die face—holes following radii.

DIE FILING BY HAND

To the great majority of inexperienced people, filing merely conveys the backward and forward motion of a file, thereby causing a certain amount of the material to be removed. To the tool-maker it is quite a different matter; it is an art by which the good mechanic signifies, not necessarily the amount of time he has devoted to the job, but the amount of real effort he has put into it to bring his work to a state of perfection. In the technical branch of any of the fighting Services, the qualifying trade test for a fitter mechanic is a filing job, and it is generally agreed that this is the best method by which a fitter can be judged.

To the improver, apprentice, or others whose experience and knowledge in this direction are limited it may be mentioned that with the ordinary back-and-forward motion of a file one cannot under any circumstances produce a flat surface. No matter how practised the operator may be, there will occur a certain amount of roll. This can be quite easily proved by putting a straight-edge on the face which has been filed and holding it up to the light, although most probably the contour of the surface can be felt by simply rocking a steel rule upon it. The correct method of finishing a piece of steel if a flat surface is required is to scrape the high spots off, having first rubbed it on the surface plate or any flat surface which has been previously coloured with Prussian blue or other

suitable material to mark it. When one is satisfied with the flatness, take a fairly large, smooth file and holding the handle in one hand and resting the other end of the file on the job, make a small circular motion, taking pressure on the file with the fingers of the other hand. Not, of course, keeping it in any one spot, but moving it gradually about on the surface until it is covered with a series of circular scratches. A little paraffin during this operation helps, and when the surface has been afterwards wiped clean and a coating of oil applied, it looks rather attractive, or at least "finished."

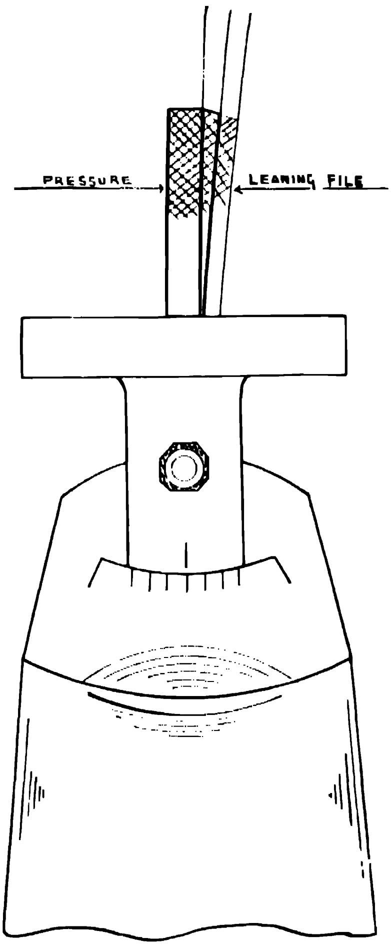


Fig. 97. Bench filing machine, showing possible error.

The filing machine is one of the greatest inventions to minimise inefficiency in a tool-room, and it is also wonderfully effective and rapid when producing a die, but if such a machine is not available, all small dies will have to be finished by hand. Many tool-rooms that produce small high-class tools provide rapid-moving bench filing machines which, if used with care, will produce any desired flat surface; there is, however, one great drawback to this class of machine which has to be noted and avoided. Owing to the fact that the top of the file is totally unsupported, when the part to be filed is pushed up against it, the file naturally leans outwards, removing much more metal at the bottom than at the top, and probably instead of $\frac{1}{2}^\circ$ that the die required, it may be discovered that the taper is about 5°, which makes a die practically useless (Fig. 97).

The usual amount of taper or draught on a die is from $\frac{1}{2}^\circ$ to 1°; any greater angle than this lessens the life of the blanking die, owing to the fact that the dies have to be continually ground to recover the edge lost by previous use. Owing to this necessary angle, or "backing off," the more that is ground off the die face the larger the die opening becomes, until eventually there is too much clearance between the punch and die for the tool to be effective, as the part that is produced will have a large burr. Hence, the lesser the amount of angle the longer the life of the die.

The question may be asked, "Why not have the die parallel?" This, however, is impossible, since in an ordinary follow-through die, when the

punch strikes it causes the metal to expand; other blanks follow, one on top of the other, and by their pressure expansion is also taking place until —before they can reach the bottom and be expelled the die will burst. Disregarding the thickness of the stock which is being cut up, necessitating much clearance between the punch and die, the blank conforms to the shape and size of the die. When it is considered that $\frac{1}{2}^\circ$ is about ·009 to 1 inch, the necessity for the inside edges of a die to be filed perfectly flat will be readily understood; also, it would be useless if a bump even of ·005 inch stood up $\frac{1}{2}$ inch down, and so ruining the job.

Before filing machines were invented, all precision filing had to be done by hand, and the new bench mechanic may be advised to do his utmost to reproduce the high-class work accomplished by the older type of skilled craftsman. It is unfortunate that the apprentice of to-day is taught so very little hand filing, as it is an art that is very necessary if one is to become a competent bench fitter or tool-maker.

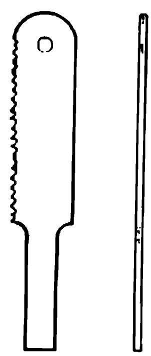


Fig. 98.—Cutter made from machine saw blade.

The mechanic who is going to make a die by hand adopts in almost every case the same principle. After the holes have been drilled as close up to the profile line as possible and about $\frac{1}{4}$ inch diameter, and the radius of one hole almost reaches the radius of its neighbour, the wall is broken away with a tool which is made from an old machine hacksaw blade, a chisel in this case being useless, unless it is to chip away some of the rags after the piece in the centre of the die has been removed (Fig. 98). Rough files are to be preferred for any metal except brass, as when these are used the amount of cut can always be governed by the pressure applied. Moreover, they do not corrode so easily. Oil is the greatest enemy to filing, especially carbon steel; it is, therefore, very advisable to keep the job clean. Even to place one's finger on a job that is being filed, trying it for smoothness, is very wrong, as the touch leaves a film of grease, which the file has to pierce before coming into contact with the metal again. It is merely a habit—by which one can usually discern the novice. Short files are better than long ones for this particular work, as it is obvious that they do not roll so much, the amount of leverage being less. The good mechanic is continually checking the surface being filed, with the square and straight-edge, as appearances may be very deceiving. It is possible to obtain, from good precision tool-makers, gauges 89° 30′, which are extremely useful in blanking die work, and one of these is shown in Fig. 99. Good hand filing is a tedious job, as it cannot be done quickly, and if there is any danger it is best to grind the corners of the file smooth.

The filing is continued and the template worked in from the back, as, owing to the taper, this is the larger end. Two-thousandths of an inch (·002 inch) appears a very large gap when the job is held up to the light, and this is the time when the tool-maker takes notice and just removes a

little from one side, or a little from one corner as required, entering the template again and again for inspection, until it is gradually worked in. The finishing touches are usually given with Swiss needle files, as, by the very fact that these files are flexible, it is made possible to produce a flat surface or reduce a definite spot (Fig. 100). Assuming now that the template is a nice slide fit in the die and can be pushed right through with a little effort, the line of procedure is to have the die hardened and tempered, and after the hole has been cleaned out with a carborundum stone and paraffin, it is usually rough surface ground.

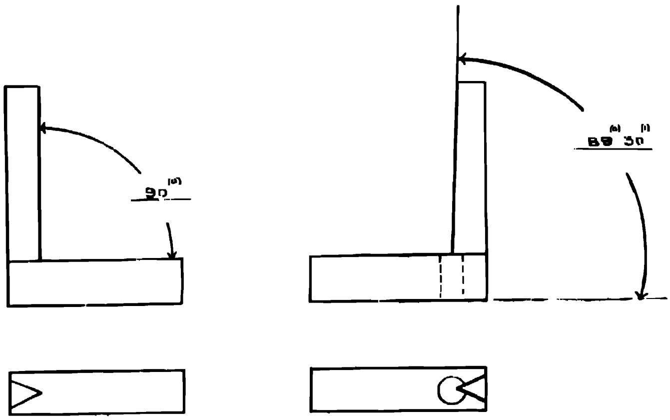


Fig. 99.—Gauge for checking die draught.

The Punch.—This is generally made up from the same material as the die, although in some very large factories where they manufacture their own tool steel, separate material is supplied for each part. For a punch of this description there are several methods of making, and also of fixing. After having been reduced down to something near the size required, one end is set out in the same manner as the die was, but when it is machined down about ·002 inch is left all round the line, which allows for shearing. This punch is now placed on top of the hardened die and after it is ascertained that the whole of the die opening is covered it is given a bump under a fly press. By this action the punch will be driven into the die about ·010 inch and given a definite mark to work to. The file now comes into operation again and the surplus metal is gradually removed. The punch is placed back again on the die face and given another bump, and so on, until it has been worked right through the die. Care must always

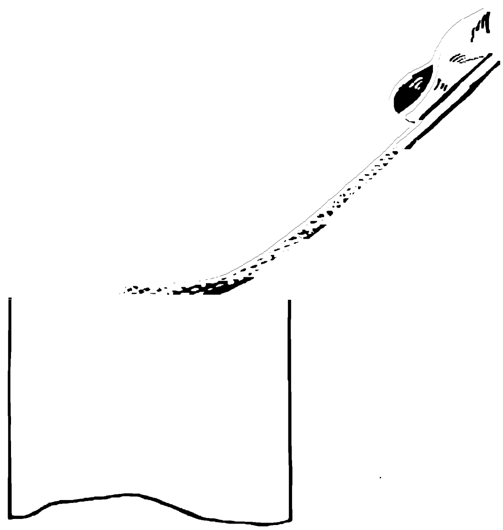


Fig. 100.—Needle file in operation.

be taken that the punch goes down perfectly perpendicular, and for that reason the tool-maker works with the precision square (Fig. 101). Now that the punch is a slide fit in the die, dependent upon the gauge of the material that is going to be blanked out, it can be reduced for die clearance, as the blank will conform to the size of the die opening.

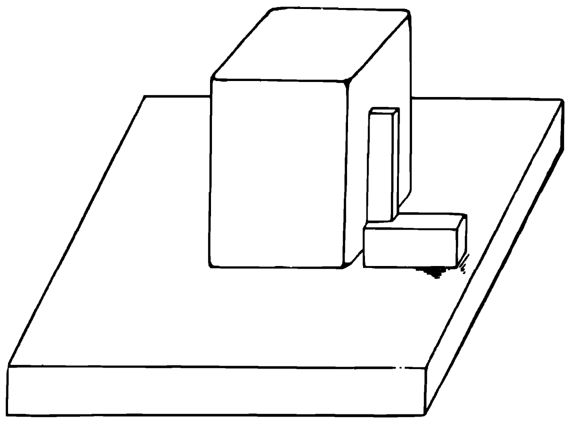


Fig. 101.—Keeping the punch perpendicular.

Punch Mounting and Fixing.—There are several methods of fixing the punch to the punch plate which carries the spigot for entering in the press ram. One is to screw the punch on to the plate and then screw the top plate on to that. The oldest method, and the one usually employed in the case of small- and medium-sized blanking tools, is to cut an opening in one plate through which the punch passes with a tight fitting, the top end being previously burred over with the hammer and the plate recessed to accept it. The other plate or punch pad is screwed on the top to take the pressure when the tool is operated in the press (Fig. 102).

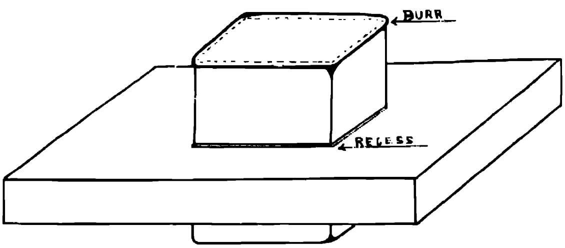


Fig. 102.—Showing method of retaining punch by burr.

There is now on the market a machine, called a punch shaper, which does away with separate mountings, and shapes the punch out of the solid, thereby eliminating a great amount of trouble. It is extremely accurate and can reduce the metal down very easily to within a margin of ·002 inch. One of these machines, by E. H. Jones (Machine Tools), Ltd., is shown in Fig. 103, while the punch being shaped is shown in Fig. 104.

The Stripper Plate.—There are two distinct methods of stripping, one being by the use of a spring stripper, the other by a positive or dormant stripper. The latter is the more frequently used and preferable whenever it can be conveniently fitted.

The spring stripper has many disadvantages as compared with the dormant stripper, for example, the spring stripper is attached to the punch and so cannot act as a guide, whereas in the case of a positive stripper it is attached to the die and acts as a punch guide, also absorbing a consider-

able amount of vibration when the punch strikes. Swiss and German tools are fitted with very thick strippers which are a good slide fit on the punch. The stripper plate having been made, it now requires the necessary opening in it. The usual tool-maker's method of procedure is to screw it back on the die and with a thin scriber mark round the die opening, after which the piece is cut out much in the same way as was the

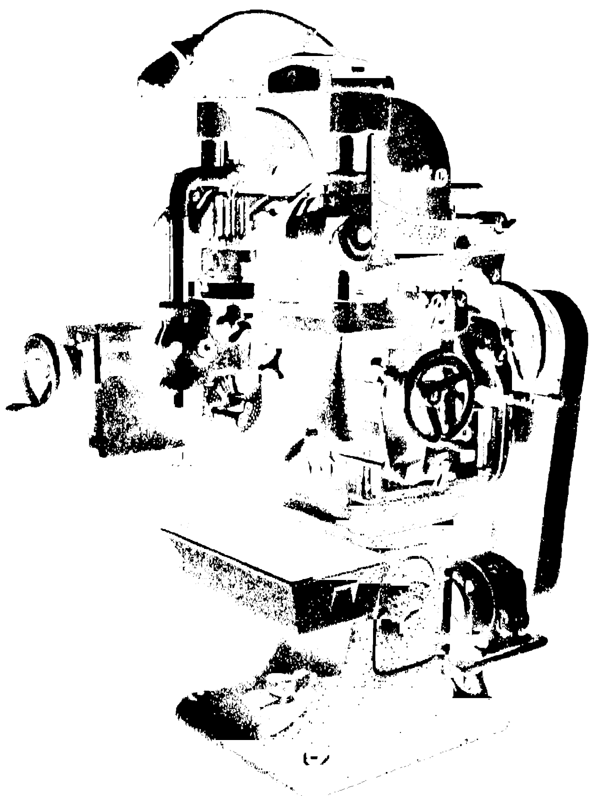


Fig. 103.—Illustration of Thiel punch-shaping machine. (By permission of E. H. Jones (Machine Tools), Ltd., London.)

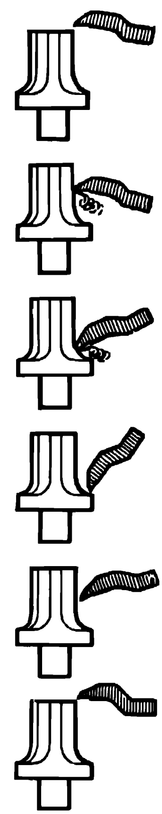


Fig. 104.—Showing stages of the action in shaping a punch with a Thiel machine.

die itself. The punch is then pushed up through the die, top foremost, with the stripper plate in position, then filed, and gradually drifted, until it goes right through.

Stock Guides.—These are two parallel strips which separate the die from the stripper plate, and which also act as guides when the stock is being fed into the tool for blanking. They require to be at least four times as thick as the material for which the tool is designed, as the stock does not remain flat but distorts considerably in the process of blanking out, so that if insufficient room is left the strip of material will be difficult to pass through

owing to it jamming. Where an ordinary pin stop is used, the guide strips must also be thick enough to allow the stock to be fed over the stop. In fitting these, they are usually clamped on to the die and the holes transferred through into the strips, just leaving sufficient overlap on each side of the die opening for the minimum amount of waste possible, without cutting it so fine that the strip will break away when being cut up, as the ragged edge will always cause trouble (Fig. 105). Some tool designers insist on one side stock guide being fitted with springs to force the material against the other guide.

Stops.—When strips of material are being fed into a press tool in the operation of blanking out, or drawing up, or pierced, or anything appertaining to the production of an article or component, it is governed by stops; these have to be decisive, quick, and positive. Stops are designed and set to minimise the amount of scrap metal, consistent with good working and to position holes, etc., in dual- or multiple-operation tools. Since press operators are usually paid piece-work rates, the true working of stops on the tool they are using plays a big part in the contents of their pay envelope at the week-end. There are many types of stop used for various mechanical production operations, and those in general use, which may be called standard types, will now be described.

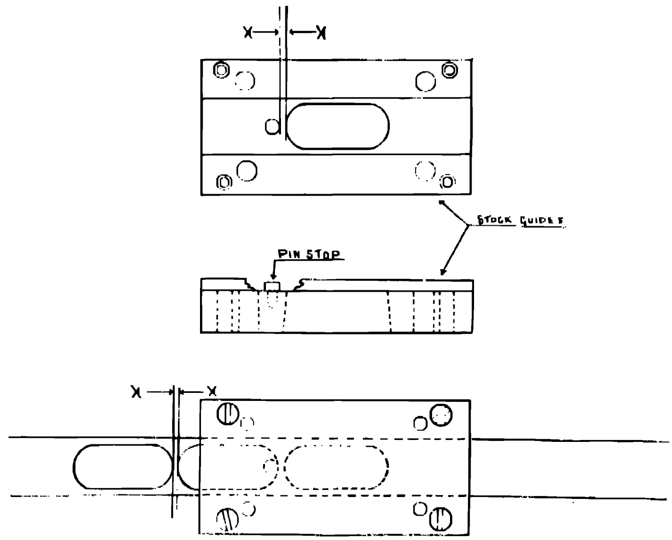


Fig. 105.—View of stock guides and pin stop.

Pin Stop.—This type is slow in operation but is suitable for large or thick blanks or where only a small quantity is needed at one time. It consists of a pin driven into a small hole in front of the die opening. The strip of material to be blanked out is pushed into the tool until it is obstructed by the stop, when the press is operated and one blank struck. When the punch is being drawn up, which is the completion of one cycle or stroke of the press, the strip of metal hits on the underside of the stripper plate and the punch continues to move upwards, being withdrawn from the material which it has passed through; when this punch is wholly withdrawn, the strip will then drop back on to the die face. It will be seen that, if at this moment the metal is pushed forward, instead of drop-

ping down to its former position it will move along until the pin stop enters the hole in the strip which the blanking punch passed through previously, and the material is now in position for the next blank, when the operation is repeated, the distance xx representing the minimum clearance between one hole and the next (Fig. 105).

With this type of stop it is only possible to operate the press one stroke at a time, instead of a succession of cycles.

Trigger Stop.—This is the universal stop used in all production shops where quantity is desired. It is very simple in construction, rapid in action, and works just as well on a press doing either sixty or 300 strokes to the minute. Most operators, especially females, when once they acquire the "touch" of a certain stop, which counts for a great deal, can feed strip into a tool with a press doing 200 strokes per minute for an indefinite period with very few failures. This illustrates the confidence gained by the press operator with a good smooth-working stop.

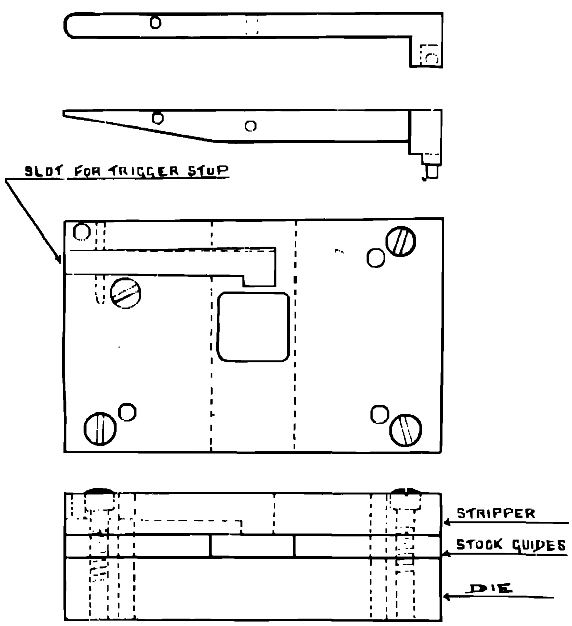


Fig. 106.—Construction of slot to accept trigger stop.

The trigger is usually made from mild steel case-hardened with cyanide or some other suitable compound to restrict wear, of which, on the stop end, there is necessarily a considerable amount. The spring which operates it is of considerable importance, and should be very lively and of medium tension; too light a spring is liable to cause failure, which usually scraps the whole strip of material; or too heavy a spring throws a great strain on the person operating the tool, which, of course, should be avoided whenever possible. The trigger stop is only very lightly lubricated, since over-oiling causes sticking (Fig. 106).

In Fig. 107 the trigger stop is shown as it is usually constructed, with the slot ready to receive the trigger, the essential clearance being somewhere between ·020 to ·050 inch. With the spring of the required length, it will be observed that it is pulling up that end of the trigger to which it is connected, thereby forcing the other end down on to the die face; it also has a side pull forcing it up against the front face of the slot in the stripper plate.

When the strip of material is fed into the blanking tool sufficient force is used to push the stop to the back of the trigger slot against the weight of the spring. The press is then operated and one blank struck, and the trip screw is so adjusted that the trigger is just depressed at the end of the stroke, when the other end will move upwards clear of the strip. When the press completes the cycle and withdraws the punch, the stop would normally resume its position on the die face, but owing to the fact

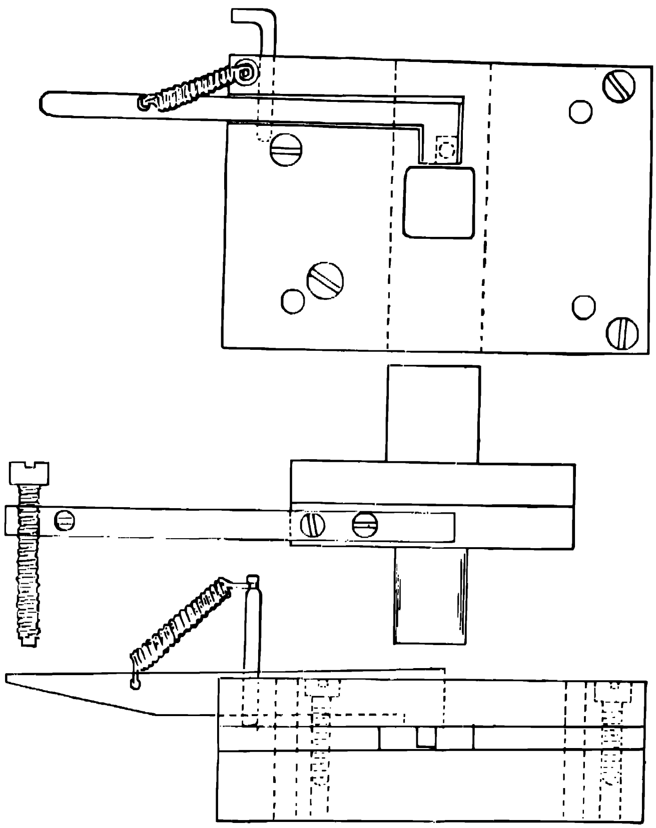


Fig. 107.—Trigger stop and trip screw.

that the spring is giving a side pull the stop will come down on to the top of the strip instead. This will then allow the material to go forward by the pressure that is placed upon it by the operator, until the stop drops into the hole struck by the punch, which brings it to a standstill. The process can then be repeated in slow or rapid succession, according to the press being used and the gauge of the material being cut up.

The Finger Stop.—This stop is nearly always used in conjunction with the trigger stop. If, for instance, one or more holes are pierced in the part to be made by the tool, or a form pierced out before the blank

is struck, then the tool must be fitted with a finger stop to govern and position the strip (Fig. 108).

The material is pushed into the tool up to the finger stop, the press is operated, and the hole or holes pierced. The finger stop is then pulled out and the material strip pushed up to the trigger stop; the press is operated again when the part is struck with the holes in, at the same time piercing the next holes. By this means the two operations are performed at one time, from which this particular class of tool derives its trade name, "Piercing and Blanking" tool.

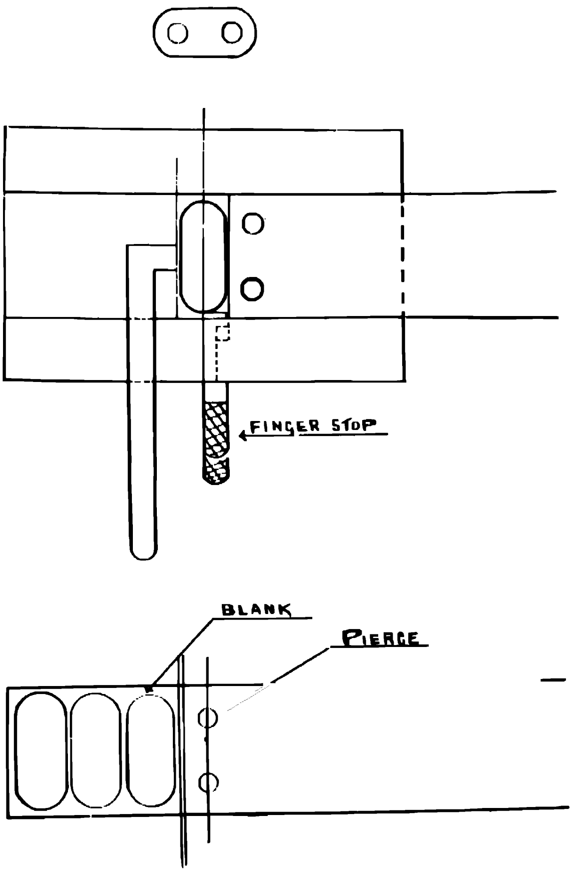


Fig. 108.—Construction of finger stop—pierce and blank.

Blanking and Drawing Dies.—There are many types of tool capable of doing both of these jobs at one blow. The tool which appears to be most efficient and possessing the longest life, although rather costly to produce, is termed the pillar-type compound tool.

In the design of a press tool, much consideration must be given to the quantities produced as well as to retaining the shape and size of the article. Firms that supply the Post Office with telephone components are held down to such close limits and such enormous quantities are required that efficient tool life is a most important factor; consequently, the majority of these firms specialise in compound tools, which ensures a parallel die.

In other trades it may be different; for example, aircraft makers, owing to continuous experimenting and the resulting modification, often make some of the crudest forms of tool. Other firms which specialise in the manufacture of the small fittings, of the type purchasable at the multiple stores, use mostly follow-on tools, as quantity is the only consideration, a few burrs and the holes getting a trifle larger being of not much consequence.

From time to time large companies, particularly those who make a very close study of the factors which affect the cost of production, alter their tool design, although in the last few years British firms have adopted the principle of a series of operations, as being preferable to doing the job all at one blow or on the follow-on principle, which can be regarded as the German and Japanese methods.

It will be easily gathered from the foregoing explanation what is the meaning of "tooling costs," and it will be realised that it is not so much the price of a tool that matters, but the cost of the article it produces, and this is entirely governed by quantity.

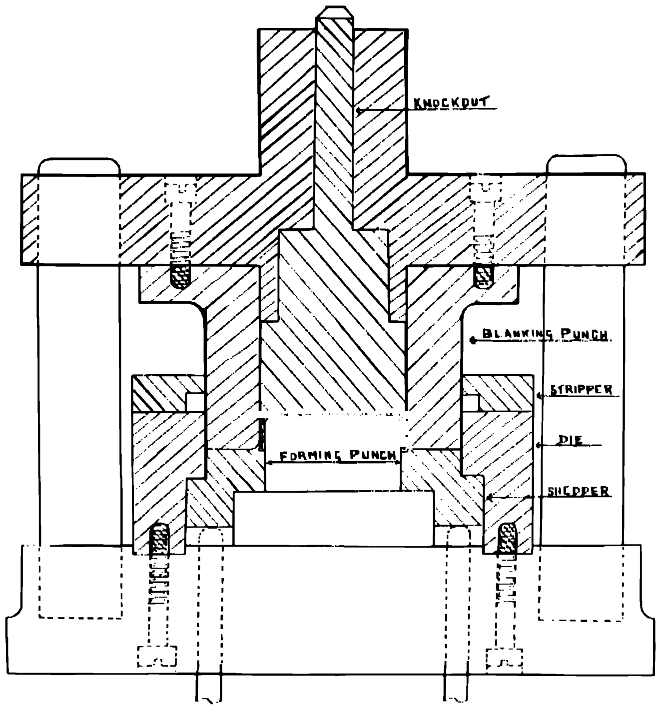


Fig. 109.—Compound tool—forming cup.

Compound Tools.—As already mentioned, this type of tool is constructed with a parallel die, or, in other words, there is no die draught or "backing off." The piece part is ejected from the top of the die, which makes any angle quite unnecessary. The tool can be ground over and over again without any alteration in the size or shape of the component it produces. The die is situated at the top of the tool instead of the bottom as in the majority of cases. It descends down on to the punch, which is a fixture on to the bottom bolster (Fig. 109).

The determination of the size of the blank in a compound tool to produce articles by blanking and forming may require careful consideration and possibly a certain amount of experimenting will be necessary. The size of the blank needed can in many instances be fairly accurately gauged by the weight. As an example of this, a sample of the component needed is made up either by temporary tools or, if of circular form, by being spun on a former in the lathe and afterwards trimmed or turned down to the exact size. The sample is now very carefully weighed on a sensitive scale, and then, knowing the weight of sheet metal per square inch, the diameter of a piece can be computed which will be equal

in weight to the sample. Should there be a trimming operation after drawing, then a small percentage is added to allow for this.

Blanking and Perforating Dies.—The terms "pierce and blank," and "blank and perforate," really mean exactly the same, in some localities the word "perforate" being used while in others the word "pierce" is preferred. It might be suggested that "blank and perforate" should apply to a tool which does the two jobs simultaneously, and, on the other hand, the tool which has to pierce the holes before blanking, although the operation is progressive and continuous, could be considered as a pierce and blank.

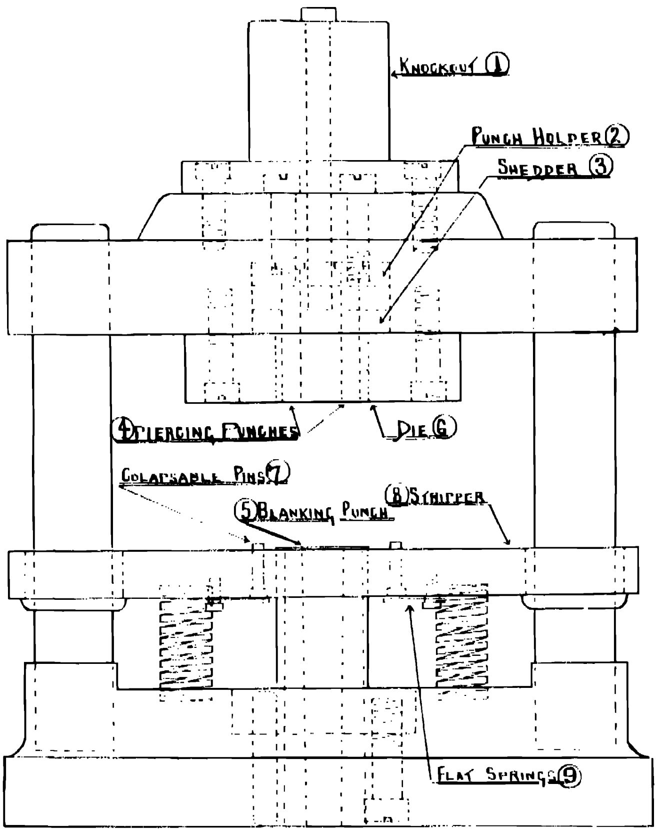


Fig. 110.—Compound tool—blank and perforate.

For blank and perforate the compound tool is ideal, as the accurate positioning of holes so necessary in high-class work, such as telephones, electric meters, etc., can be easily effected. Fig. 110 is a sketch of a tool used in this type of work showing the various details (Fig. 111), and the stripper plate (Fig. 112), so that the process can be clearly visualised. This type of tool is used extensively in the production of small high-class electrical fittings in nickel, brass, fibre, etc. It is not very rapid in action, and sometimes requires a compressed-air pipe attached to the press to keep it clear of obstructing pieces of material. When blanking and perforating fibre, the blanks usually return to the strip, but this is easily overcome by having a little spring pin projecting above the blanking punch which will then throw them off. The die and punch being quite parallel, they can be ground over and over again, and if the perforating holes are very slightly "backed off," say by about one-quarter of a degree (15′) (which is sufficient if accurate), the component will retain its shape and size without the slightest variation even after the tool has produced millions of stampings.

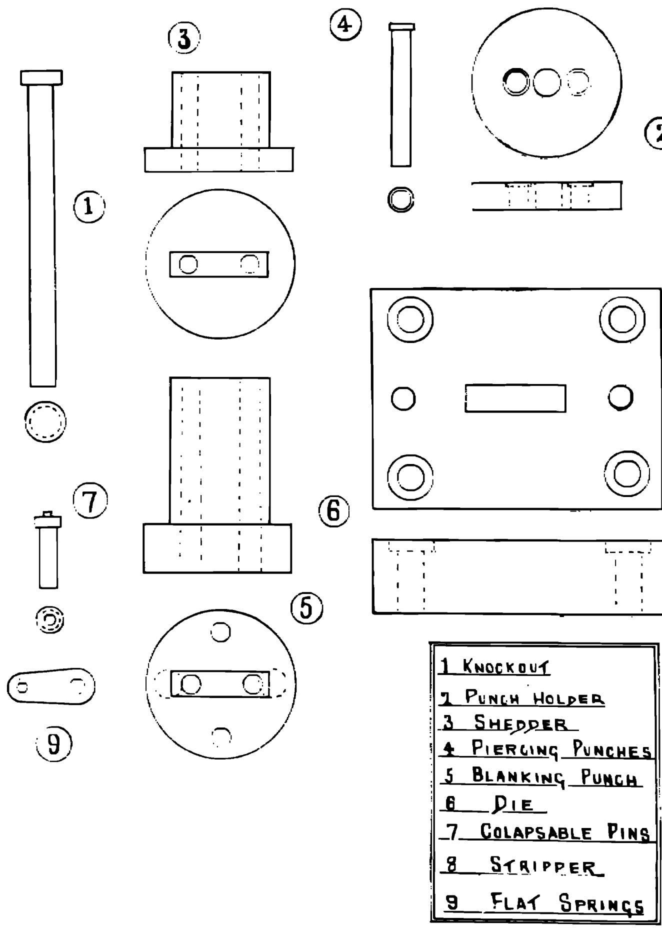


Fig. 111.—Details for a compound tool.

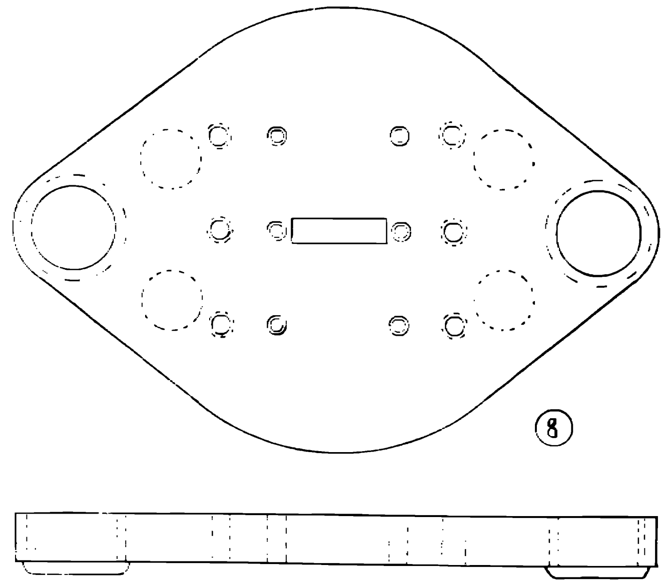


Fig. 112.—Compound tool—the stripper plate.

Perforating Sheet.—Some types of perforating presses for working on flat material are designed to perforate the entire width at each cycle of the press. The job is fed in with various types of mechanism, such as "roller" or "gripper" feed, and moves forward after each stroke mechanically. The holes are usually perforated two rows at a time, the first set being at an angle to the second. Some presses are designed to do this hole-staggering by a mechanical device, shifting the sheet from one side to the other, in which case only one row of punches is used. For perforating heavy sheets, where one design only is needed, the guides which locate the material are made movable, so that perhaps ten to twenty holes or patterns can be pierced and then the sheet moved over and another series punched. There is another design of press, in use where a firm specialises in this class of work, which by modifying the feeding does away with the necessity for more elaborate and larger dies. This is termed the "interrupted feed," and is so arranged that the material can be fed in by irregular movements. The economical advantage of this will be at once realised, as, for instance, if the perforations were equally spaced they could be pierced with the aid of an ordinary trigger stop, but being unequally spaced, if this special mechanism was not available the die would have to be designed to produce the staggered or irregular spacing.

Perforating Cylinders.—The tools used for perforating the sides of cylinders are very similar to blanking tools, excepting for certain alterations in the design to conform to the circular surface, instead of working on the flat. Taking as an example a shallow shell with twelve piercings round the rim, this would be done with a single punch, but the arbor to which the component is temporarily fixed would revolve on a spindle, by an automatic cam action, operated by the press. When the desired number of perforations had been made, the press would be thrown out of action, also by a cam, to enable the component to be removed. Up to a few years ago, a big trade was done in the fabrication of oil-lamp and gas-burner galleries (Fig. 113), which, owing to their technical needs such as the inlet of air for consumption, and the springiness of the tags to hold the glass chimney, offered a great field for

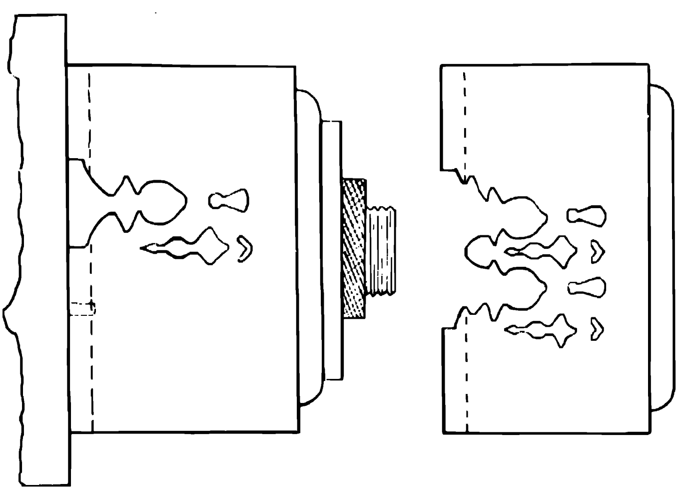


Fig. 113.—Piercing a lamp gallery.

ornamental perforation, and many were the inventions and mechanical devices adopted in the process of fabrication. One great advantage was prominent in the construction of these galleries: they had to be made from very hard brass, and this makes for a clean hole in piercing. The hardness of the brass was produced by burnishing, or by imposing a hardening draw just before perforating.

It is not to be supposed that these automatic, revolving, perforating tools are in general use through the country; indeed, that is not so, and many small factories turning out good clean articles produce them with dies of the simplest nature in fly presses. Many small shops do not use presses at all for this class of work, but a device which is fastened down on a bench, and provided with a fairly long handle which operates the punch-holder (Fig. 114). The first ornamental clipping on the gallery becomes the location which "picks up" on a pin, one piercing is made, then the component is moved round, and so on, until completed.

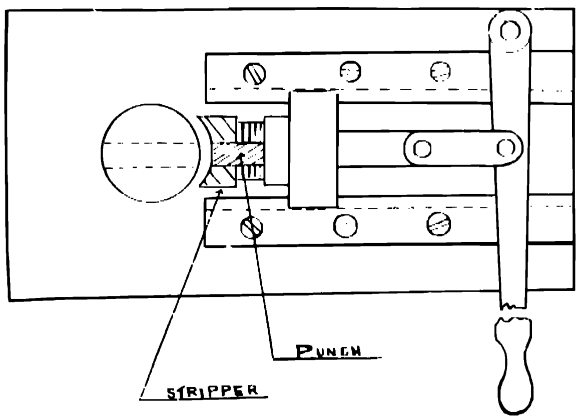


Fig. 114.—A bench fixture used for piercing.

Soft-steel Dies.—In the majority of cases with high-class tools, the dies for these would be made from best-quality cast steel, hardened and tempered, but it will be understood that owing to the fantastic shape, these dies are very costly to produce, and also, owing to the fabrication being composed of very thin metal, the amount of die clearance must be minute, otherwise a burr will result, which in ornamental piercing of a finished article is entirely out of the question. The method adopted in many small shops where elaborate design in piercings are required is to make these dies of high-speed steel, but leaving them soft. It is very surprising, to those unacquainted with such matters, to note the length of time that these tools will stand up before the component begins to show a burr. When this does occur, the die is sometimes gently "tapped in" with a small hammer, or even forced in by rubbing a burnisher over it and then just shearing the punch through again.

Stripping.—This is a very important part of the operation where ornamental piercings are concerned, and must in all cases conform to the outer radius of the article being pierced. It is usual to have small strippers backed up by springs, as, if ordinary stripper plates were used, especially in the case of the lamp galleries, the tabs would have a tendency to lift and distort. The strippers are made a nice slide fit on the punches, and in the case where more than one are needed, each has a steadying

effect on the other. Where rubber is substituted for springs, it is advisable to have laminations of soft rubber, similar to that which a motor-tyre inner tube is composed of, in preference to a hard block.

Triple- and Multiple-action Dies.—Triple- and multiple-action dies, as the term signifies, implies the adoption of three or more distinct operations in conjunction with each other to produce a component with one cycle of the press, such as, in triple action: blanking—drawing—stamping; or in a multiple action: blanking—drawing—embossing—piercing.

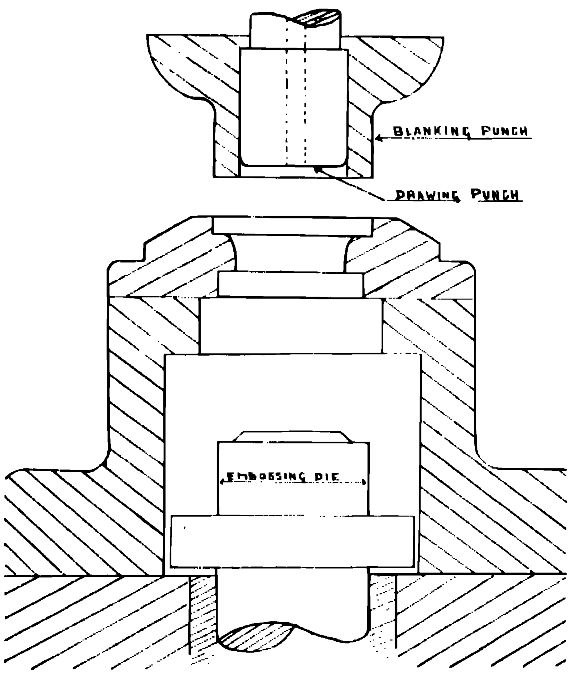


Fig. 115.—Example of triple-action die. Blanking—drawing—embossing.

This type of tool is preferred in some engineering factories where cutting the cost of production is a feature of the business; as the action is rapid the process is continuous and the formed part delivered at the bottom and not at the top as in most forming tools. An inclined press is used and the pieces slide back by gravity, usually into boxes, and are thus ready to be carried away. In the operation of the die, the blank is cut by the punch, which continues its pressure while the cup is drawn by the central forming punch. The piece part is then carried downwards until it engages the stamping or embossing die, which is mounted on a separate ram and performs its individual operations on the upward stroke. This can be fancy embossing, lettering, etc. On the upward stroke the component is stripped from the forming punch and falls away on its own accord. This type of tool (Fig. 115) is used mostly for can lids which require lettering, or fancy tops for packing jars, also seamless tins used as containers for fish paste, etc.

CHAPTER 6

DRAWING DIES AND THEIR OPERATION

THERE are many varied examples of drawing dies in use at the present day in mass-production factories, some very crude, others elaborate and expensive. No hard-and-fast rules seem to be employed in the selection of the type of tool; it is merely a matter for the personnel to decide the tool which will be used. It is probably not an exaggeration to say that in 50% of drawn fabrications, the method adopted could be improved. This does not necessarily imply that the people concerned in producing the article are at fault; they may be quite conversant with the fact that there is a more efficient method, but it is a very difficult matter to scrap a set of press tools, costing perhaps £500, and re-design at a similar, or perhaps a greater cost, to do a job that the firm with the same tools have in all probability previously manufactured in millions.

Nearly everything in the mass-production engineering factory has been evolved and not invented outright. There are naturally many individuals anxious to accept the credit for certain designs in most of the elaborate and wonderfully efficient tools that are in use at the present time, but if it were possible to trace back to the beginning of the production of any particular type of job, the above statement would probably be found correct in nearly every instance. Many of the very tricky deep-drawn components fabricated at present were evolved as a result of several years of progress. Perhaps in their original form they were made by a tinsmith or some other sheet-metal worker, as these craftsmen were in the past the cleverest metal-workers of all. Gradually, however, the original design was improved in order that production could be made more efficient and rapid. Take as an example domestic utensils of a few years ago and to-day; the old-fashioned tin kettle with its seams and bits of solder, compared with the "drawn-up" article on sale now. The majority of these articles are fairly easy to make with the necessary tools and presses, and if the product will permit of a few crinkles, like many of the cheap utensils on sale in the stores at present, they are so much the easier to produce.

For the bottom of a saucepan or kettle a disk is developed and cut out on a revolving cutter—that is if a blanking tool is not available—and it is just pushed through a die in a single operation (Fig. 116). If it requires a more perfect draw, the finish to be smooth and uniform, then it will be drawn in a die constructed for a double-action press. An ordinary type double-action press is constructed with two distinct rams

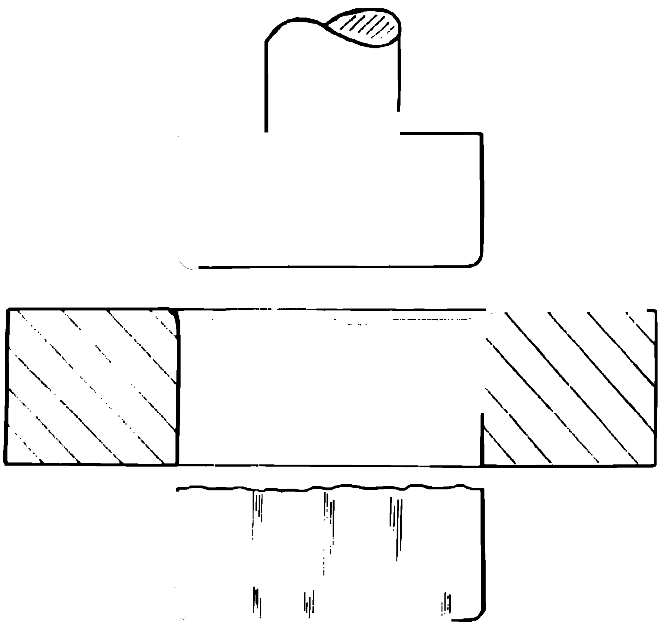


Fig. 116.—Simple die for producing kettle bottom in single operation.

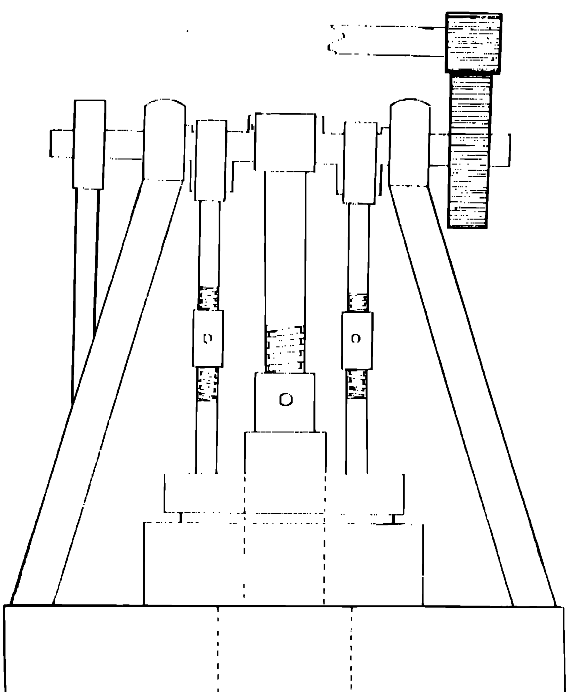


Fig. 117.—Explaining the design of a double-action press.

working in unison. One ram controls the pressure pad which descends and holds the material to be drawn, while a central punch descends and draws the metal (Fig. 117). In order to complete the cycle, the upper tool ascends usually through the pressure pad, which strips the "drawn-up" part from the punch and then itself returns to the top. In the drawing of very thin material to any appreciable depth, this type of tool is absolutely necessary. If, on the other hand, the gauge of the material being drawn is heavier and no double-action press is available, then probably it can be drawn and finished to specification by two or more operations in a single-action press. If it is a very deep-drawn cylinder or container, with a certain gauge of material called for, and upon experimenting it is found that the percentage of "breaks" is too high, then the thickness of the metal would have to be increased and the tool modified to suit. With fairly substantial metal of $\frac{1}{16}$ inch thickness or thereabouts, it can be drawn in multi-operations and one or two annealing processes superimposed, but this is not practical with a deep draw of very light stock.

In some large works, especially those employed on motor-car body production, they have a portable heater, mounted on a wheeled frame, accommodating an assortment of high-pressure gas jets which are adjustable. These are arranged and set to heat the sheet metal in those spots where the greatest draw takes place and where it is liable to crack. The machine is then placed adjacent to the press and the sheet metal locally heated before drawing.

Shallow Drawing Dies.—Some short time ago the writer was responsible for the construction of a batch of tools to produce a paint-box to contain water colours. In the normal way it would have been a fairly simple job to design, but there were two distinct features to consider. First, that the material—which was mild steel, approximately ·010 inch thickness—was to be painted white on one side and black on the other before being drawn. There were an assortment of sizes which varied from twenty to forty compartments (Fig. 118). The second feature was that the box, when finished, had to be produced at a cost of less than one penny. After considerable thought and consultation, the definite conclusion was arrived at, that the top or the bottom, in each case, would have to be produced in two operations on single-action presses, to gain speed and rapidity of action. The first operation would be blanking from the strip. The second operation would be to draw up the sides and emboss in one blow, and by these means it was possible to keep within the estimated cost. The drawing and embossing tools in this instance were made first, as to develop a blank from any theoretical formula was entirely out of the question owing to the great uncertainty as to how much metal the embossing would take up.

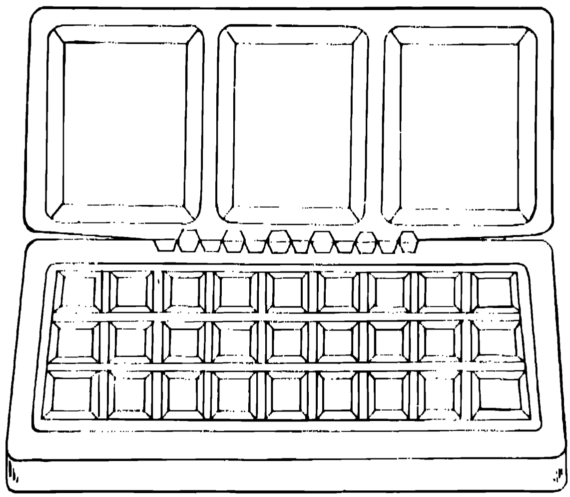


Fig. 118.—The metal box—to contain water colours.

The blanking tools were made of the pillar type, with cast-steel bolsters, and the dies were machined out of the solid. It would, perhaps, have been preferable if the dies had been made in sections, as one die cracked in operation. This, however, did not prove such a disaster as was at first imagined, as it was possible to cut the cracked section away with the grinding machine and insert a piece about 2 inches wide. One other alteration had to be made and that was to recess the bolster $\frac{3}{4}$ inch deep by end milling, to withstand the outer pressure of the blanking stress. When the die is in a complete ring this is not necessary. Very

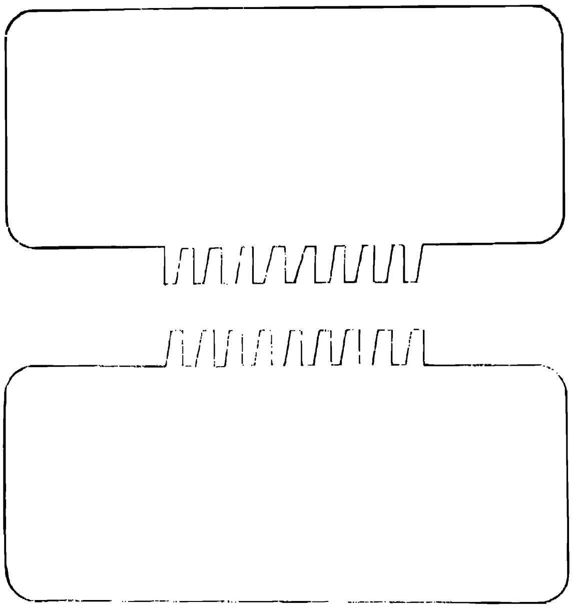


Fig. 119.—Blank used in forming the metal box.

large tools, even when the die is in sections, are not always recessed for thin material, but good stiff dowels, $\frac{5}{8}$-inch diameter, are found sufficient to withstand the outward pressure.

The sheets of metal were cut by a guillotine to a size suitable to be fed into the tools for blanking out (Fig. 119). These blanks were then drawn up and embossed in one blow with the special tools designed for the purpose (Fig. 120). The tools did the job and produced the article with great rapidity, but the amount of stress and hammering was considerable. Great trouble was experienced in getting springs to withstand the repeated blows and they were constantly renewed.

It will be seen from the illustrations of the tools, that the design is essentially to make a single-action press do a double-action job by means of innumerable springs, some of which are shown.

It is possible, that after the tooling costs were taken into consideration, the job proved unprofitable, and the trouble experienced served as a lesson in the design of subsequent tools, *i.e.* to avoid springs wherever possible. If tools must be of that nature, then rubber should be used in preference to springs, or better still, if in any way practicable, the tool should be so designed that the action is positive, and experience teaches that this line of design is the best to follow.

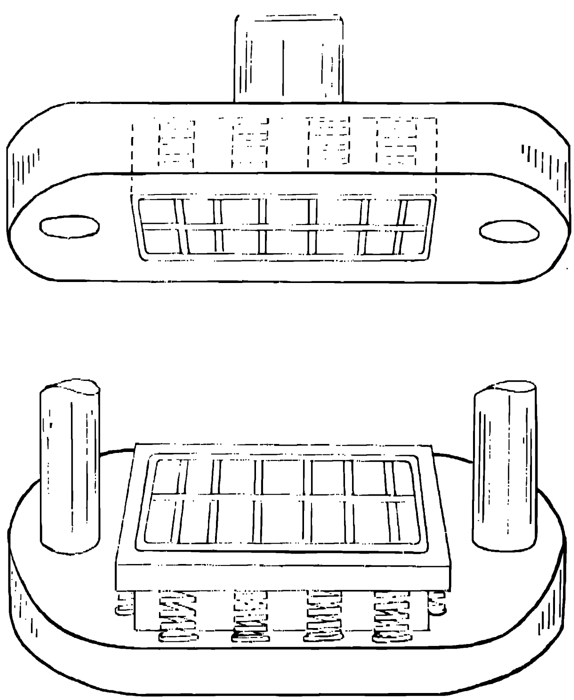


Fig. 120.—Single-action tool used for forming metal box in one operation.

As an example, it may now be explained how this job might have been attacked, although by this method the tooling would have cost double and the production costs would also have been doubled, but against this the maintenance costs would have been exceedingly small and the tools might have " stood up " to the production of ten times the quantity.

Improved Method of Production.—In the first instance, a blank could have been developed that would have allowed for the embossing, the drawn-up edge, and about ·020 inch trimming all round. It may have been possible to guillotine these, although the square corner may have caused crinkling, and it must always be borne in mind that the more one can shorten the outer edge, to reduce resistance, the more chance there is of drawing the metal and not stretching it. The hinging tags could have been left for a later operation by notching, and the blank left plain (Fig. 121). The embossing tool in this instance would have been quite plain and without pillars, these being unnecessary, as the female and male embossing would have aligned themselves without other aid.

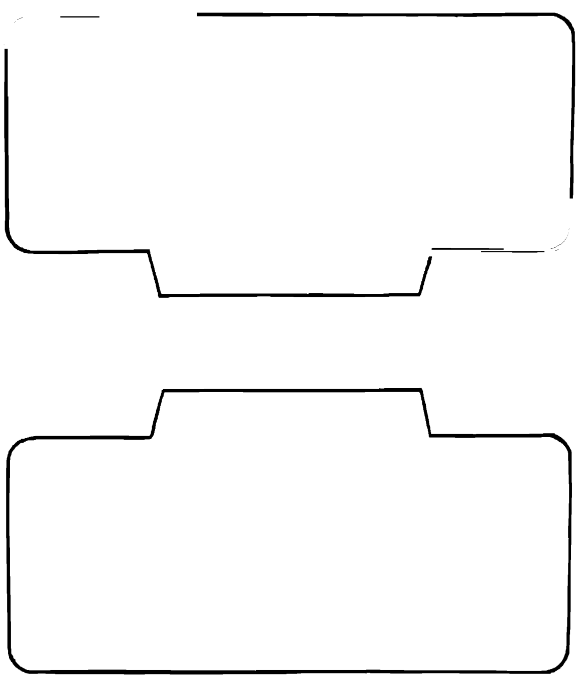


Fig. 121.—Blank to be used in another method of producing metal box.

The next operation could have been trimming and notching, with an ordinary follow-through type of blanking die to have trimmed the already embossed metal to size and notched the hinging tags. After this, the sides would have been drawn in a double-action press by a tool with a solid top and bottom representing the embossing, while an outer punch descended, drawing down the edge (Fig. 122).

Other Shallow Draws.—Shallow cups and rectangular flanged lids may be made from blanks or strip, on both single and double-action presses, the tools being very similar to those used for cupping, with the exception that usually the dies are constructed of a solid bottom and either with a spring or positive ejector. Dependent upon the quantity to be produced, the tools are made from hardened carbon steel or good-quality mild steel, and in many present-day tool-rooms, skin-hardening by the cyanide process plays an important part.

For the production of parts such as headlamp bowls or reflectors the

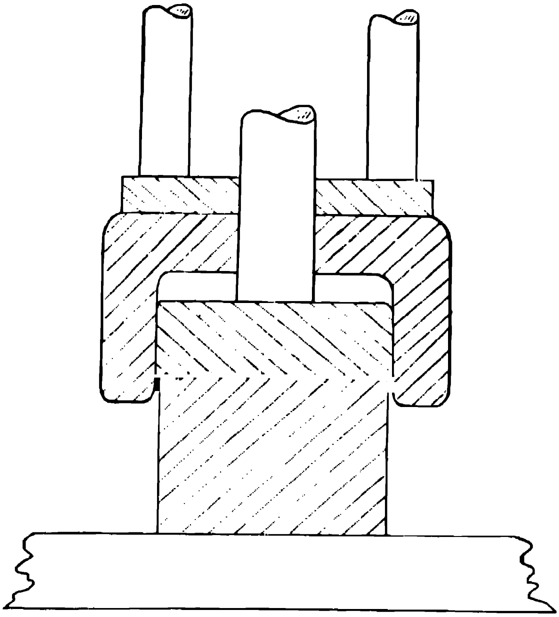


Fig. 122.—Finally forming edge of box in double-action tool.

tools consist of just a shallow ring and the drawn part conforms to the shape of the punch. The pressure applied to the blank-holder or pressure pad is very considerable, in order to prevent too much slip, as the forming is by a process of stretching and thinning the metal. There is a limit, of course, to the amount that metal can be stretched and thinned, and it is only by experience and experimenting that a balance can be found between slipping and stretching, and the material must, of course, be sufficiently ductile to avoid fracture (Fig. 123).

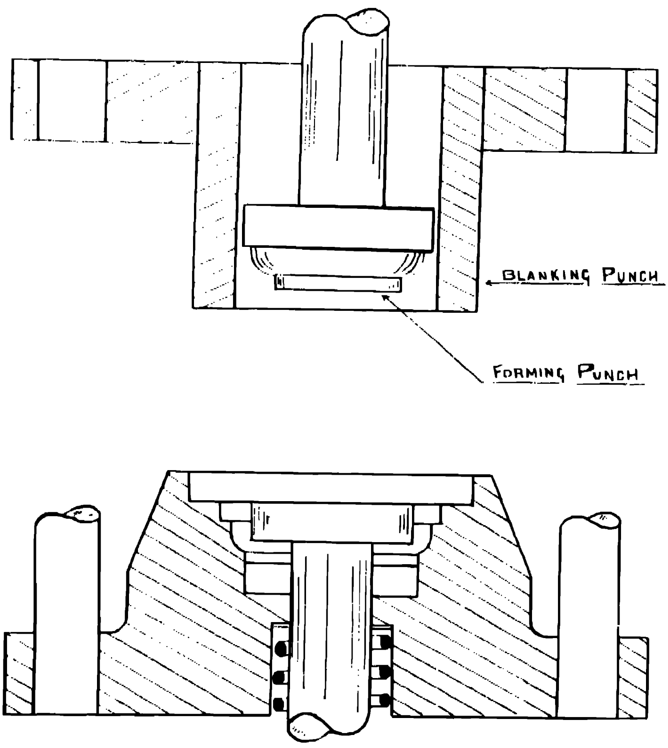


Fig. 123.—Forming shallow cups—double-action.

In the drawing of very large products, such as motor-car body wings, owing to the unusual area occupied by the tool and the inability to trap sufficient metal as resistance against the draw, the outer edge of the top die has a deep groove running round it and the bottom die is fitted with a half-round beading to correspond. When the upper die descends, the material being drawn is trapped by the bead, which exerts sufficient pressure, while the central punch draws the metal. These wings are drawn in pairs

FORMING BY DIES IN A DROP-HAMMER. NOTE PART OF THE FINISHED PRODUCT IN THE BOTTOM RIGHT-HAND CORNER OF ILLUSTRATION. (The De Havilland Aircraft Co. Ltd

and afterwards split down the centre, as will be seen from Fig. 124. The majority of these tools are constructed in cast iron, the bottom die doing practically nothing, except to act as a blank-holder by supporting the bead while the material is drawn by and conforms to the punch. The punches for some of these tools weigh as much as half a ton and are formed, after being cast to somewhere near the shape, by the Keller machine, which is a very large profiling machine operating various-sized milling cutters, which trace out the shape from a wooden model. The presses used to operate these tools are very large, some of the beds being 12 feet long. They are mostly of the double-crank type. The ram to which the top die is fixed is operated by compressed air, while the ram controlling the central or drawing punch is electrically driven. The use of these presses considerably simplifies this particular class of metal drawing, as the pressure holding the blank or sheet can be regulated to suit.

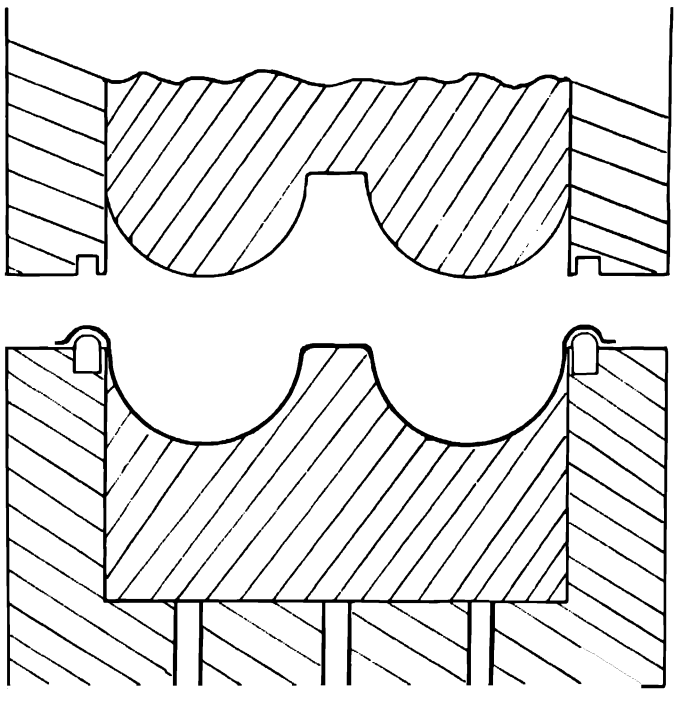


Fig. 124.—Method by which motor-car wings are drawn showing beading.

Deep-drawing Shells.—In the drawing of deep shells much experience is necessary to produce the required depth without employing any needless operations. When dies for progressive operations are designed and obtain excessive reduction in diameter or changes in form that are too acute, the metal will be over-stressed, if not fractured. On the other hand, if unnecessary re-drawing operations are employed, the cost of production is considerably increased. At a point between these two extremes there is a safe and economical course to follow and it is the ambition of the tool designer, in collaboration with the engineer, to determine just where this course lies.

An essential principle in any sequence of operations is to arrange for decreased reductions to be performed, if possible, at successive stages, also to divide the work between reduction of total diameter and reduction of metal thickness. The great importance of this distribution of the total work

cannot be over-estimated, and it may be said that most of the obstacles to efficient production are from a lack of appreciation of this principle. It is frequently found that greater reductions are attempted at later stages than at the beginning, which is decidedly wrong. The reductions which may be performed vary a great deal with the particular product; for instance, much more work can be performed upon heavy-gauge material than light. In single-action re-drawing, the reductions which may be adopted are in the region of 30, 25, 16, 13, and 10% in the successive draws, but for light-gauge products, necessitating double-action presses, the first re-draw should not amount to more than 20%. In the process of re-drawing operations, which require only an alteration in the external diameters, with little alteration in the thickness of the material being used, a number of different methods can be adopted. In Fig. 125 A and B the drawing operations are carried out with blank-holders in double-action presses.

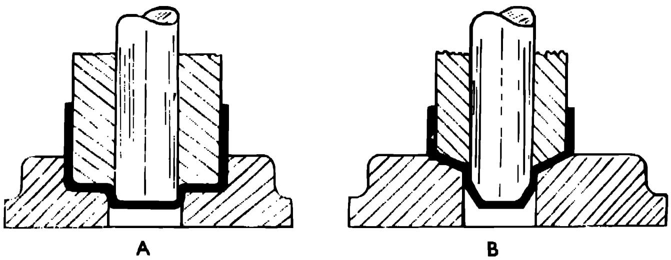


Fig. 125. Re-drawing by double-action tools A and B.

In the first operation for a re-draw, as in A, the metal has to make two right-hand bends, which imposes considerable strain on the material, whereas in B the blank-holding surface has approximately a 30° angle, so that the metal makes only two bends, through 60°, thus considerably easing the strain. For methods of reduction, as in Fig. 126, this process is usually employed for fairly thick-walled products, where a deep cylinder is required and annealing stages are possible. It will be seen that in method B the work is divided between the two steps so that heavy reductions may be used, in fact, reductions up to 40% can be made by this method. For the group of re-drawing operations, as in A, single-action presses are almost invariably used. A hole is drilled in the punch to avoid the formation of a vacuum, which would make the stripping of the component much more difficult.

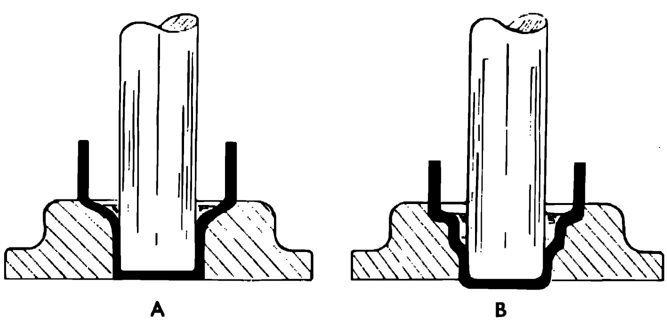


Fig. 126.—Other methods of re-drawing A and B.

The " inside-out " method of re-drawing, shown in Fig. 127, is favoured by many designers on account of its simplicity. It is particularly suitable for rectangular shapes, as the reduction is considerable.

Further examples of re-drawing methods, through which one can visualise the various forms that a component should take in the process of fabrication, are illustrated in Fig. 128, the blanking having been done separately with a standard tool. The first draw of a flanged case is shown at A, and this needs very little explanation, except that it was a tool of the " ejector " type operated in a double-action press, although a very similar job could be done on single-acting presses, and provided that the punch and die have exactly the right amount of clearance and that the material is to the stipulated size, there is no reason why it should not always be done so.

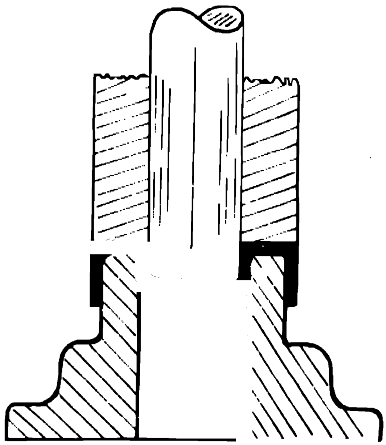
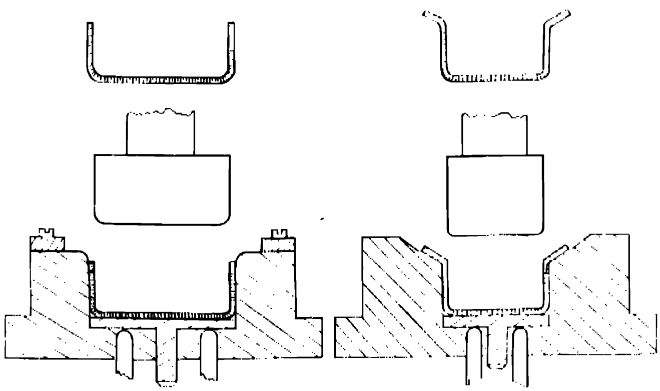


Fig. 127. Design for very deep re-drawing.

Fig. 128 B shows a first re-draw which reduced the size of the body from $2\frac{3}{4}$ inches to 2 inches, a single-action press being used for this operation, fitted with a platform and a spring-loaded plunger, which served the dual purpose of maintaining the case in a vertical position and also ejecting it after drawing.



A B

Fig. 128.—Single-action re-drawing to produce flanged shell, A and B.

The next operation was to reduce the bottom end of the case preparatory to the final draw, and was accomplished in a tool similar to that shown in Fig. 129 A, a single-acting press with a positive knock-out being employed.

The final draw must be done in a double-acting press (Fig. 129 B), as it is necessary for the flange to be held very tightly whilst the drawing is completed. In the tools for the second and third draws, strippers were fixed to the bolster with mild-steel pillars and the component placed in the entrance to the die underneath the stripper bars. Usually in a component of this shape it holds to the punch, but should anything occur causing the product to fracture or split, then it will stop in the die. As

it is a trouble to extract the part, and this may possibly hold up production, it is always best to forestall this and have ejectors, as well as strippers, to both punch and die, if only to give a start, and this will usually keep the tool clear. The fact should, however, be emphasised that, wherever possible, a punch with a taper, however slight, should be used, as this is always a great help in drawing and stripping. It frequently happens that a component of the deep-drawn variety is required to be made " parallel " by the production department when actually there was no reason whatever why the product called for should not have a taper of, say, 1°.

The Eliminator Box.—In the life of a tool-maker, if one moves about a bit, from shop to shop, one is almost bound to come up against varied circumstances, and it is of great assistance in gaining experience. It must not be supposed that all production factories possess an adequate staff such as tool-planning department, engineering department, tool designing and drawing department, and so on; indeed it is often far from being so. Many large firms possess none of these useful personnel, and the practical tool-maker may be said to be the pivot upon which the factory revolves. The tool-maker is consulted by the works manager or foreman about a certain job, which it has been previously decided shall be manufactured, and he is nearly always instructed to keep the cost down. This raises the question as to how many operations are required. But for good results one should be very wary in cutting operations, as generally the onus of responsibility rests solely on the tool-maker. This, of course, is where experience is so valuable.

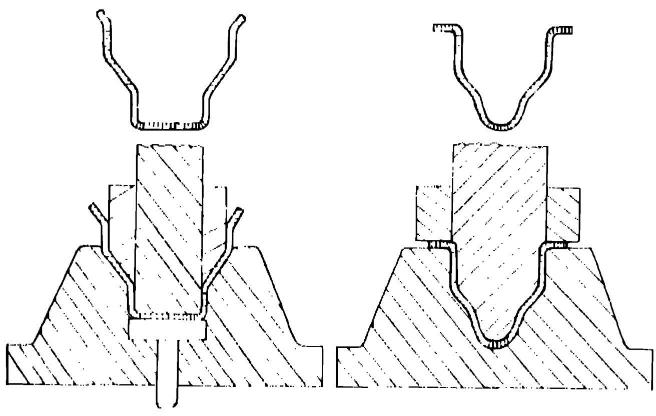


Fig. 129.—Third and final draws to produce flanged shell, A and B.

Round jobs are always the easiest to produce, rectangular and irregular shapes the most difficult, especially if sharp corners are called for, so, wherever possible, avoid them. Thus, in the production of a box for an electrical eliminator on cheap lines, the writer was rather doubtful as to the possibility of doing it in two draws and had left room to superimpose a further operation, but it was successful, and the percentage of " breaks " very small. The box (Fig. 130) measures $6 \times 4 \times 2\frac{1}{2}$ inches deep, of ·025-inch mild steel, and to attempt to accomplish this in one draw followed by a squaring operation was rather drastic.

For a cheap job of this description a cast-iron die and a mild-steel punch are used, and it is surprising how long a cast-iron die will last with adequate lubrication, and, moreover, with the constant slipping of the material on the surface, it becomes highly polished and hardened. In a difficult draw of this acuteness the use of a cast-iron die is to obtain balance, which is essentially a tool-maker's job.

The die was made from a good close-grained cast bolster, 4 inches thick, and the rectangular size of the box was drilled and slotted out, including the radii in the four corners. The bolster had been previously machined on either side and was afterwards scraped by hand to ensure perfect flatness, which is very necessary. The pressure pad was also made of cast iron, machined, and scraped flat. The die was then given a $\frac{3}{8}$-inch continuous radius on the top side as a lead in, smoothed off, and nicely polished with emery cloth.

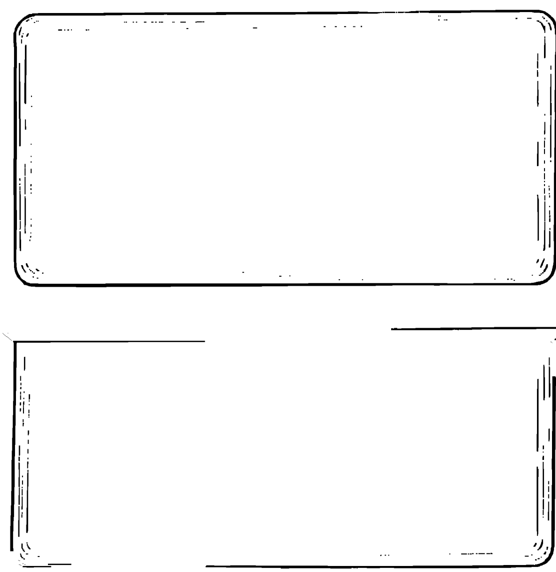


Fig. 130.—A deep rectangular box as explained.

The punch for the first draw was machined from mild steel, with a $\frac{5}{16}$-inch continuous radius round the bottom edge, also a 1° taper from top to bottom. This taper is essential and it plays a very important part in the production of a clean job. Assuming that the die opening is 6 × 4 inches and the material to be used ·025-inch mild steel, the stock cannot always be guaranteed to size, so that an allowance of ·030 inch clearance between the punch and die should be made, which will make the punch approximately 5·940 × 3·940 inches at the top or largest end. The punch is 4 inches long with 1° taper, so that the bottom end of the punch will be approximately 5·804 × 3·804 inches, allowing then, when the punch first hits the material, at least $\frac{3}{32}$ inch clearance between punch and die, gradually decreasing as the punch descends, so that no ironing takes place until the end of the run in.

The tool for the first draw was then mounted in the double-action press and bolted down very firmly. In the try-out of tools where any side stress is likely, the necessity for absolute immovability cannot be overestimated, as any movement destroys balance, and owing to the fact that no two trial pieces show the same result, it is impossible to make progress. As in this case it was not intended to make a blanking tool, but only to mark off

templates, after final development a rough calculated size of the blank was worked out. In the development of a drawn product it is always advisable to keep on the minimum or short side, otherwise progress will be hampered (Fig. 131).

With lubrication the trial piece was " drawn up " and afterwards carefully examined. The experienced man will probably turn the die round, after marking it, to find which gives the best result, and then the balancing job begins. Perhaps two corners are good, one has broken, and one has crinkled. The scraper is used round about on the top of the die where the break had occurred and about ·001 inch removed to lessen the pressure. On the corner that has crinkled, a little more weight on the pressure pad and so on, until, with patience and perseverance, the whole of the four corners draw up clean and unbroken (Fig. 132).

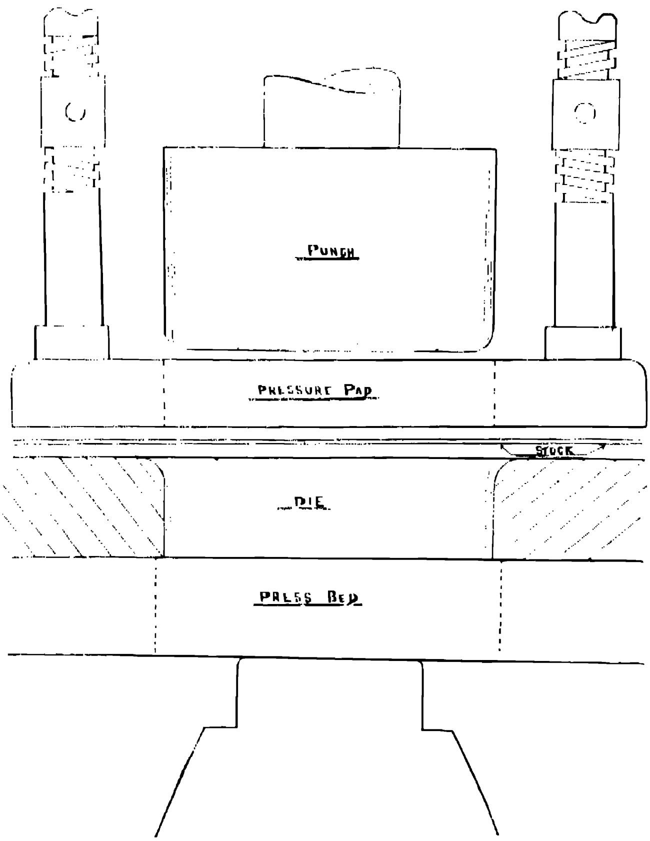


Fig. 131.—Double-action tool for producing box.

The next operation was squaring up and forming the bend on the bottom edge. A die was made from cast iron about 4 inches thick, and milled out to the requisite size, with 1-inch square steel inserts all round the top edge. The punch was made in this instance from cast steel to exactly the same size as the previous one, but with the bevel, and it was afterwards hardened and tempered. In the bottom of the die was fitted a large-headed knock-out as a precautionary measure, and four small airways were filed in the underside of it, to stop the bottom of the drawn box blowing in, also an air passage was drilled up through the punch to stop the reverse occurring (Fig. 133).

All that was then needed was a trimming tool for the top edge and this was quite a simple matter. A trimming tool of the blanking type was

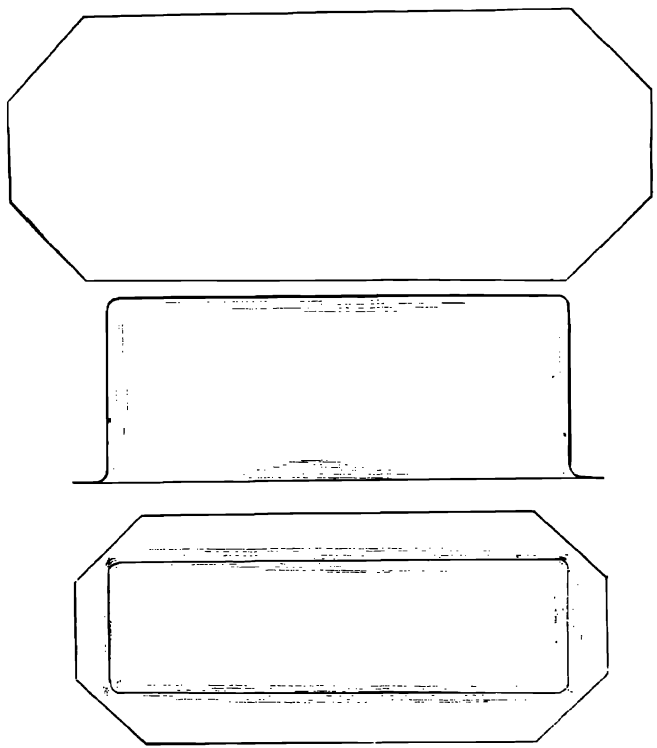


Fig. 132.—Blank and first draw for metal box.

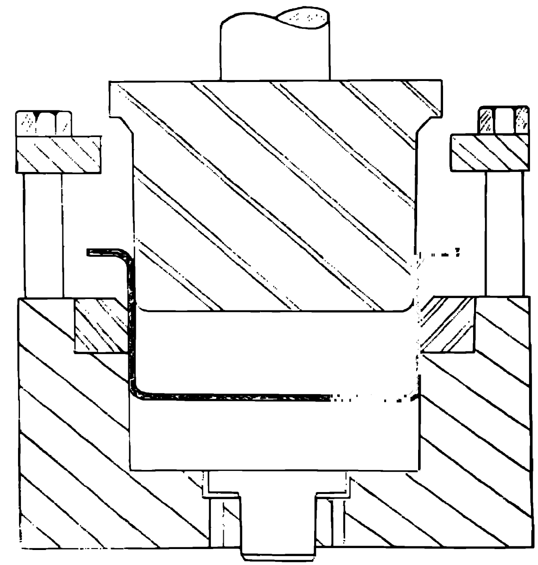


Fig. 133.—Second draw and bevel-tool metal box.

made, with a die in sections. On to the bottom of the blanking punch was a pilot which picked up the drawn box, also a spring stripper was fitted to strip off the trimmed portion, and the whole job was now complete (Fig. 134). Many thousands of these eliminator boxes were subsequently produced with this tool.

Multiple-drawing Dies.—This type of tool is usually employed by production managers, with the idea of reducing costs by minimising labour. These tools, however, especially if they are of the automatic indexing variety, sometimes prove unsatisfactory owing to increase in maintenance costs and production time losses. But simple tools for multiple piercings, where the perforations are too close to each other for a single- or double-operation die to be practical, proved very successful.

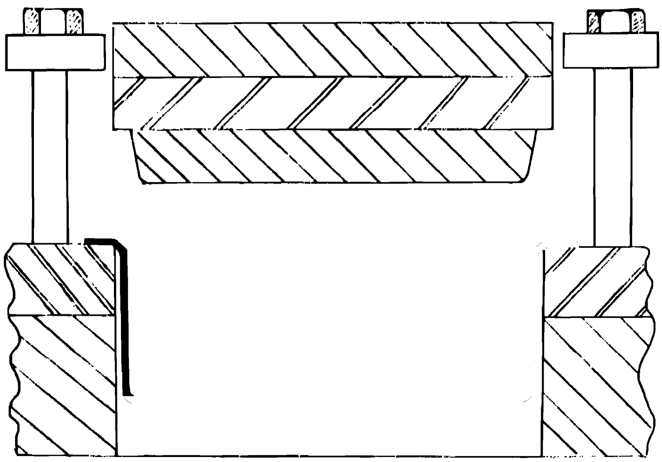


Fig. 134. Final trimming tool (" blanking type ") for producing rectangular box.

They are constructed with a die usually recessed into a bolster but able to turn freely. To the upper part of the tool is affixed a handle and the revolving movement is indexed by a spring pawl. If a fabrication requires a large number of piercings and embossings, this amount would be divided by three or four. The press would be operated by single strokes and after each blow the tool would be pulled round, until the pawl entered the next notch, when the press is operated again (Fig. 135).

The automatic indexing multiple-drawing die is a rather complicated piece of mechanism. The lower part of the tool usually accommodates the punches and is also fitted with an automatic indexing device, which controls the tool in its revolving motion, allowing each drawing punch to do its special job in turn, successively reducing the size of the drawn part. Although each punch and die is performing an individual operation, a complete product is delivered at each stroke of the press. During a complete revolution of the tool the whole of the operations are performed, until the complete product passes over a clearance hole and

drops out. The material is fed in by roller or "gripper" method, and provided the tool does not break down, a very rapid and cheap method of production is obtained. This method is seldom used for high-class articles, but for products that have to be manufactured at highly competitive prices, such as a butterfly opener on a polish tin. An example of a piece made in five draws with a multiple-drawing die is shown in Fig. 136.

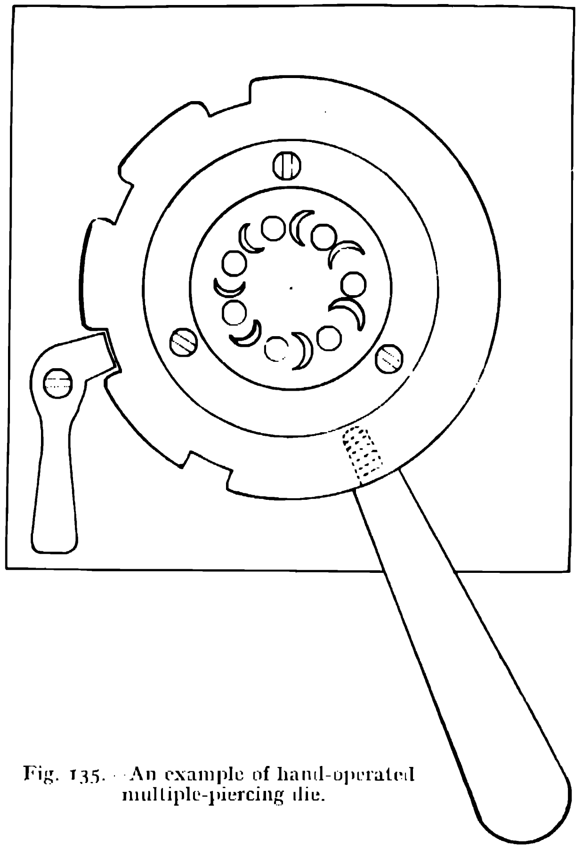


Fig. 135.—An example of hand-operated multiple-piercing die.

Many components produced by forming dies are very similar to those which have been fabricated in drawing dies. Although in many instances one term is used for the other, or vice versa, it is as well, if possible, to determine some line for classification. Undoubtedly the term "forming tool" should only be applied where the component produced distinctly conforms to the shape of the punch and die and resembles them in form, shape, and size. As an example, if a piece of metal is forced down into a die, both die and punch having previously been made the shape of the article required to be formed, and merely by a bending action the metal is forced into the desired shape, then this can be termed a forming tool. Where the part produced does not necessarily conform to the shape of the die and the form has been obtained by the thinning and stretching of the metal, then this can be considered a drawing tool.

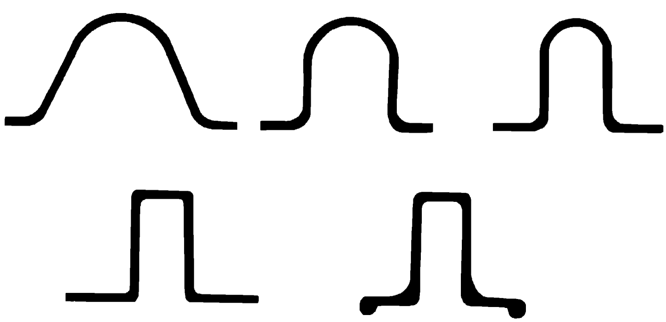


Fig. 136.—Five operations in a multiple tool.

Simple Drawing Die.—An extremely simple design for a drawing die is shown in Fig. 137. The blank has been previously cut in a standard-type blanking press; it is then placed in this tool and located by means of a shallow recess formed by having a circular hole, the same size as the blank, cut out of a piece of $\frac{1}{8}$-inch flat steel, the plate being then screwed on to the die face. Some shops are in the habit of having recesses turned in the die to accommodate the blank, but this is not the best method to adopt, as, if at any time the rim of the cup has to be increased or decreased and the die has been hardened, it is a difficult matter to alter the size of the recess.

When the punch descends, it forces the blank through the die opening as shown, thus forming it into a cup. As the press ram ascends, the part is stripped from the punch by means of spring pins. These stripper pins are not really a necessity, as it is very unusual for a piece-part of this description to return through the die, unless the stock is very much undersized.

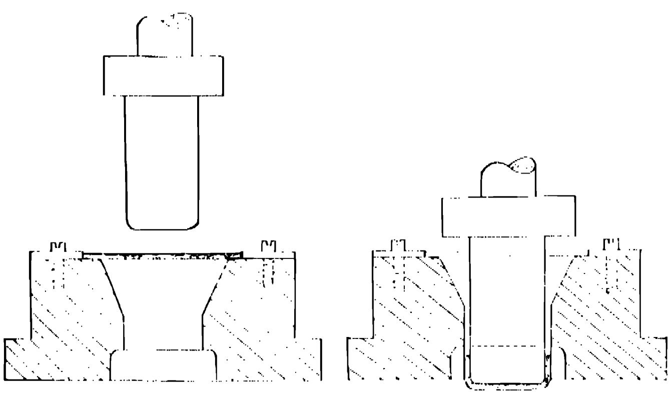


Fig. 137. Simple-type drawing tool—forming shallow cup.

Simple Re-drawing Die.—When a cup or shell has to be of a greater depth than approximately half its diameter, and if the material called for is of fairly heavy gauge, it is re-drawn in successive operations, dependent upon the depth required; by plain reducing dies in single-action presses and by a process of reducing the diameter and transferring it into depth: primary shallow shells of large diameters are transformed into deep shells of smaller width (Fig. 138, A, B, and C). In single-action re-drawing operations of this description, the amount of reduction must be done gradually and the part forced over a large smooth radius, otherwise, if the re-draw is done abruptly or suddenly, a groove is formed in the piece-part at every successive draw, which cannot be eliminated.

Inside Blank-holder Dies.—For thin work of any considerable size, a re-drawing tool of the inside blank-holder type is used, especially for long cylindrical parts where considerable reduction is necessary, as this would be liable to create crinkles. The previously formed cup is held by a blank-holder or pressure ring on the inside, as it passes between the lower bevel edge of the die and holder, while the punch descends. The pressure ring prevents the formation of crinkles, which might occur if thin material is being drawn and not adequately held.

These dies are used in double-action presses, as one ram is needed to

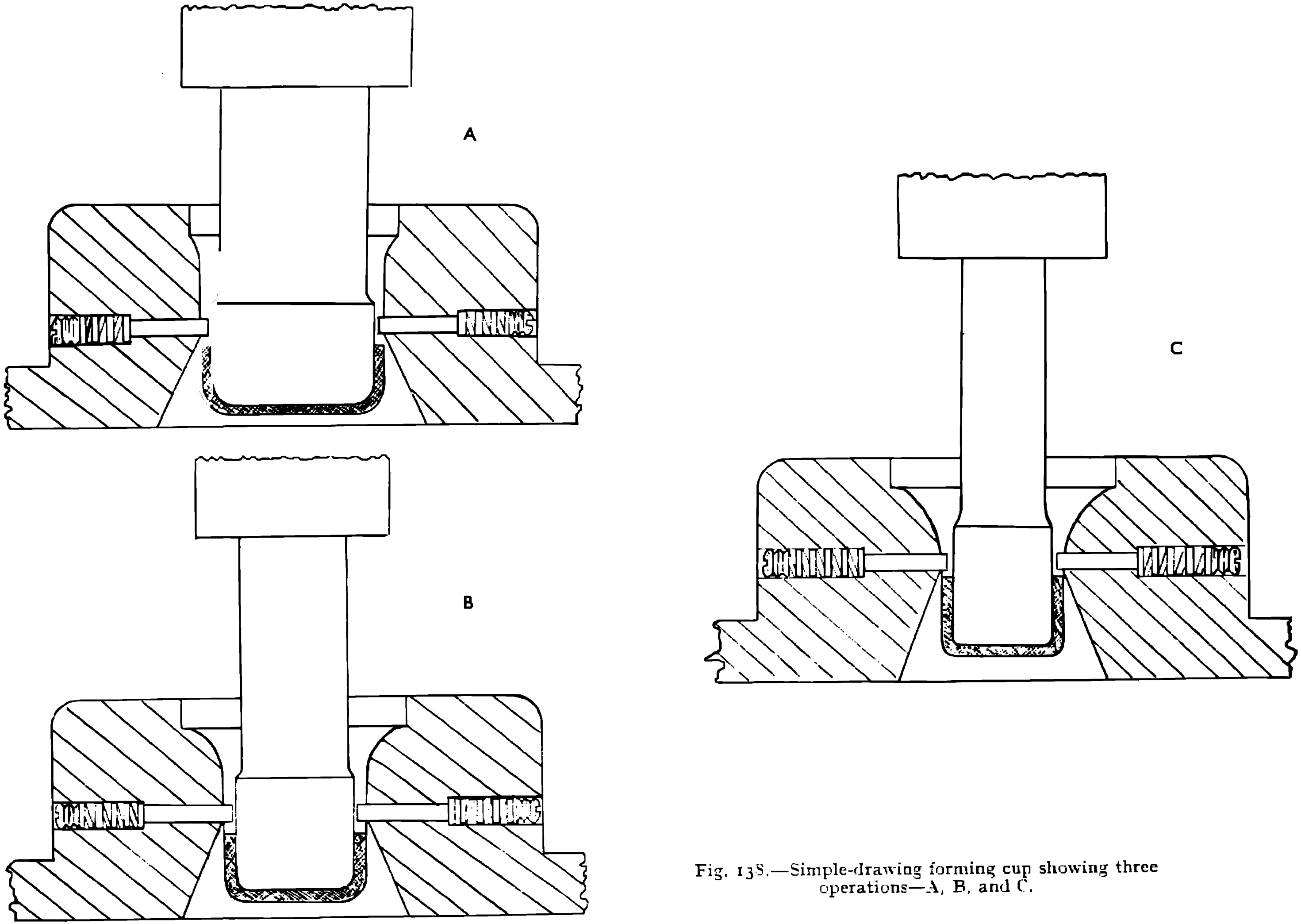


Fig. 138.—Simple-drawing forming cup showing three operations—A, B, and C.

exert pressure on the blank-holder, while the other ram operates the drawing punch. When constructed for the production of large articles, the dies are frequently made from cast iron, moulded by a special process and treated to give a very dense and uniform texture to the metal at the working surfaces. Steel rings are often set into cast-iron holders to form the drawing part of the die and the pressure ring is made from a steel casting, which adds considerably to the life and durability of these tools (Fig. 139).

Simple Draw and Pierce Tool.—There are many varied designs for the drawing and piercing of a shallow component, as this shape and class of article is in great demand for many purposes. The following tool, which was possibly unique in its simple design, construction, and operation, will be of interest. The component was made from 14-gauge cold rolled steel—blanked, drawn, and pierced, in two operations. Great care had to be exercised in setting this tool, as a great deal depends on the pressure applied by the rubber buffer, which is of the kind known as "the London-type buffer." If the pressure is too great, the diameter of the piece-part will be larger than the opening constructed to receive it in the die used for the second operation. But, on the other hand, if the pressure is insufficient, then crinkles will form in the shell, and these, when the final operation is performed, may develop into fractures.

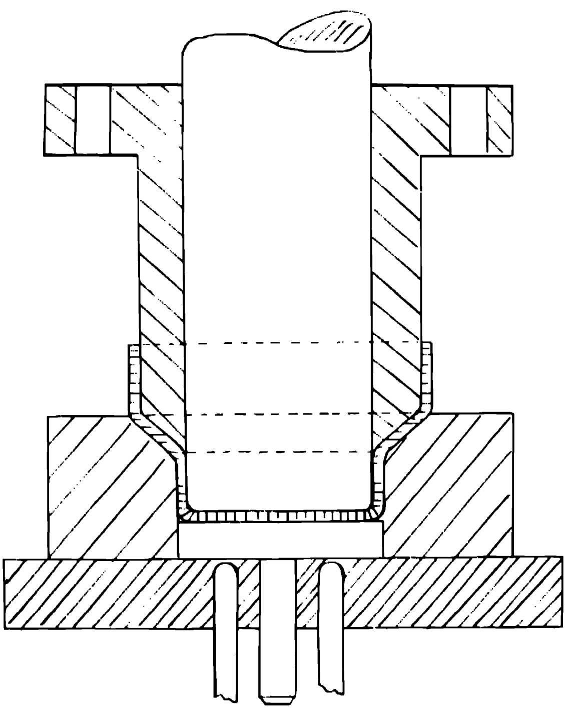


Fig. 139. Example of a double-action inside blank-holder type drawing tool.

The tool for the first operation of blanking and forming is of a simple compound type. The strip is fed in, underneath the stripper, and when the top tool descends, with the outer edge cuts out the blank, the disk being gripped by the punch coming into contact with the die-holder forced up by the rubber buffer (Fig. 140). The downward travel is continued, while the piece-part is drawn over the dormant punch at the bottom. With the upward movement of the ram, the tool separates and the drawn component rises clear by the action of the buffer on the

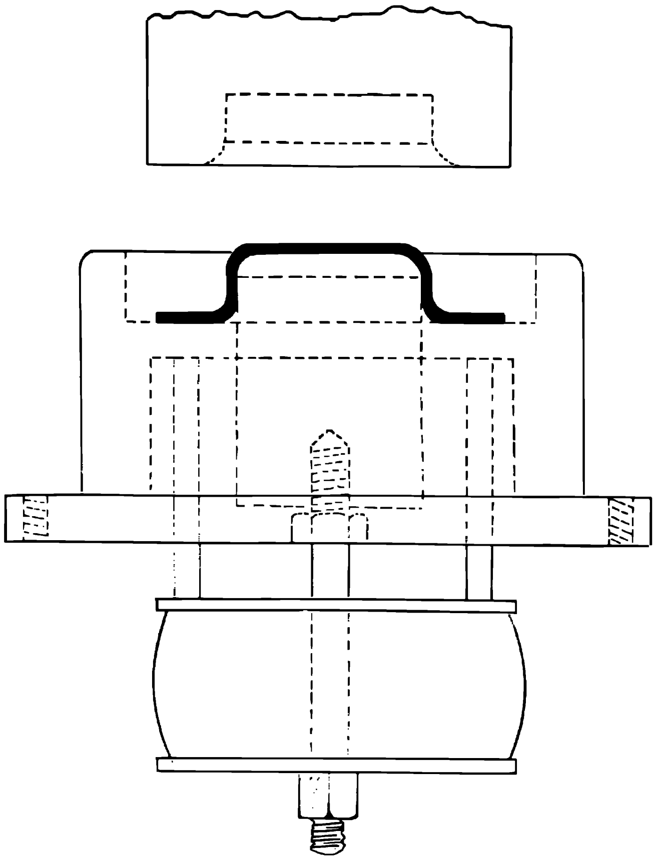


Fig. 140.—Forming shallow cup—first operation.

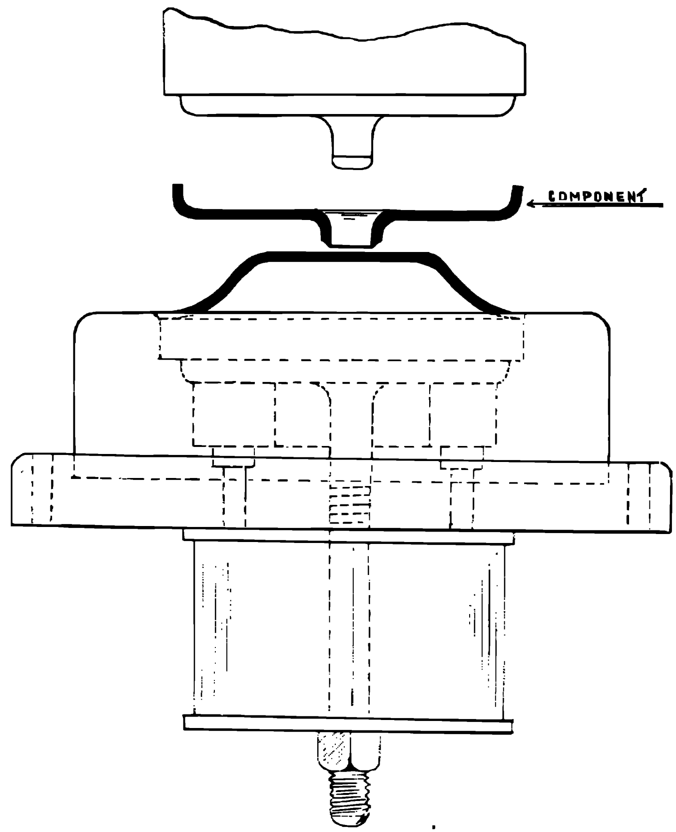


Fig. 141.—Re-drawing and piercing—second operation.

blank-holder, and if used on an inclined press, will naturally fall clear by gravity.

The final operation for this job is rather tricky. The component is placed on the tool upside down, and when the pressure is applied the outer rim curls upwards, until it hits on the shoulder at the outer edge of the punch. The downward movement is continued, completely turning the centre portion of the product inside out, finally piercing it at the bottom of the stroke (Fig. 141). Upon the return the component is carried up on the piercing punch until being stripped off by the fingers placed one on each side of the die, entering a groove on the punch.

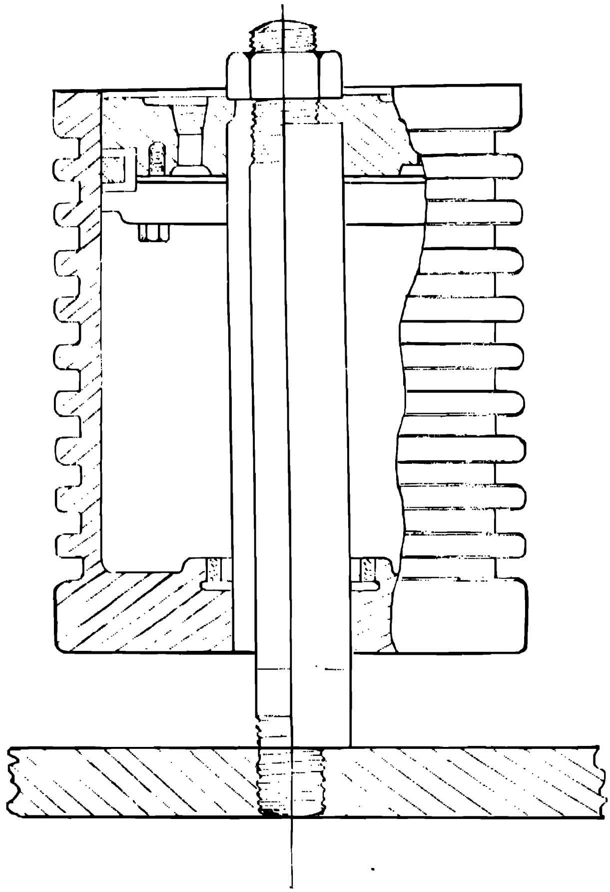


Fig. 142.—Illustration of pneumatic die-cushion.

Die-cushions.—Die-cushions of the pneumatic variety are used extensively in large production factories for obtaining uniform pressure when drawing metal on single-action presses, and they have proved very satisfactory. Various types of these accessories have been developed, mostly by American firms, and an example is shown in Fig. 142. This cushion is designed especially for small work, and to facilitate rapid production is usually used on an inclined press. In this design the piston is stationary and the cylinder moves, the piston being supported by a suspension rod which screws into the bolster. The bottom ends of the pressure pins are either resting on the top face of the cylinder or an additional plate made to receive them. Compressed air at the required pressure is admitted to the cylinder through the opening shown. Between this inlet and the compressor there is a container and regulating valve, so that the exact pressure needed for each product may be adjusted.

On larger presses of the double-crank variety several die-cushions may

be required, but these are of a different design. The cylinder in this instance remains stationary while the pressure pad, which is large enough to support all the pressure pins, is mounted upon the piston rods. The number of cushions used depends on the size of tool and the pressure pad that is going to be used, the latter usually fitting into the press bed.

These die-cushions are also made of the double-piston pattern for use on double-crank presses, which may be of either the single- or double-acting types. Three-piston die-cushions are also made for heavy-type double-crank presses. Where the pressure needed for forming a part is uneven and may cause tilting, a three-piston cushion may be used on one side and a single- or double-piston machine on the other, to equalise the pressure.

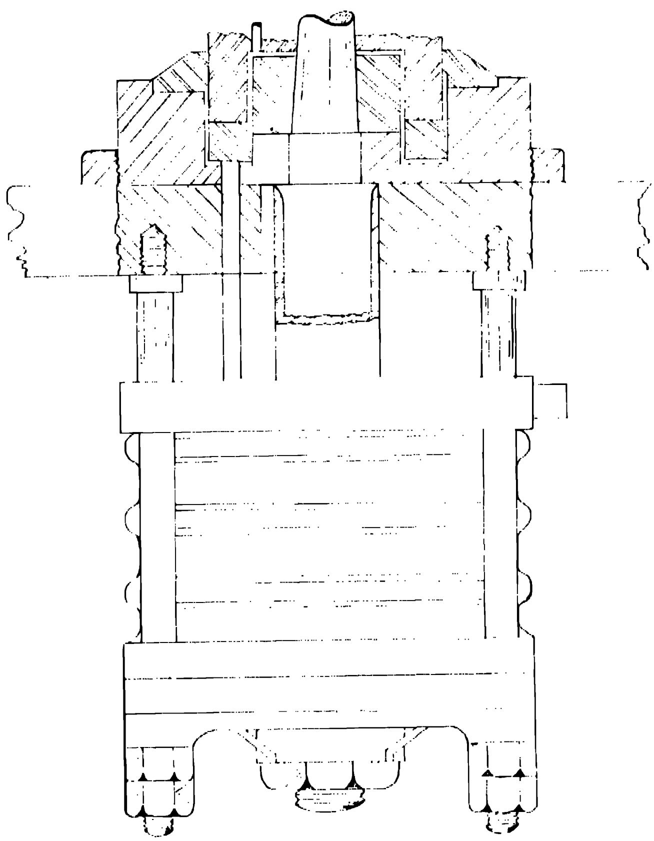


Fig. 143.—Die-cushion used on heavy presses.

For the purpose of blanking and drawing a cup and also piercing a hole in it, a special die-cushion is made with a hollow shaft, which allows the slug punched from the component to drop through it. A further type of die-cushion is fitted with a three-way valve, to allow the air pressure to reduce or escape at any predetermined position of the stroke, which can be regulated and adjusted by setting small cams placed adjacent to the press. All standard die-cushions are designed to be used with the usual air-compressor plant, which is now to be found in most production factories.

There are instances where the pressure for blank-holding is insufficient with the ordinary type of compressed-air cushion, and greater pressures are then obtained by the use of the hydro-pneumatic design of die-cushion. This type uses a liquid, usually lubricating oil, instead of air to gain the necessary pressure. The oil is stored in a tank and enters the cushion

through a cam-operated valve, which works in conjunction with the ram crankshaft. When the ram descends, the pressure pad is moved against the oil, which is forced through an air-controlled relief valve, back to the container. The relief valve is air-controlled, thereby allowing the operator to make a record of the pressures used on each job, the valve varying the resistance to the passage of the oil (Fig. 143). The use of die-cushions is becoming more and more prevalent, and they are of great benefit to modern scientific engineering production.

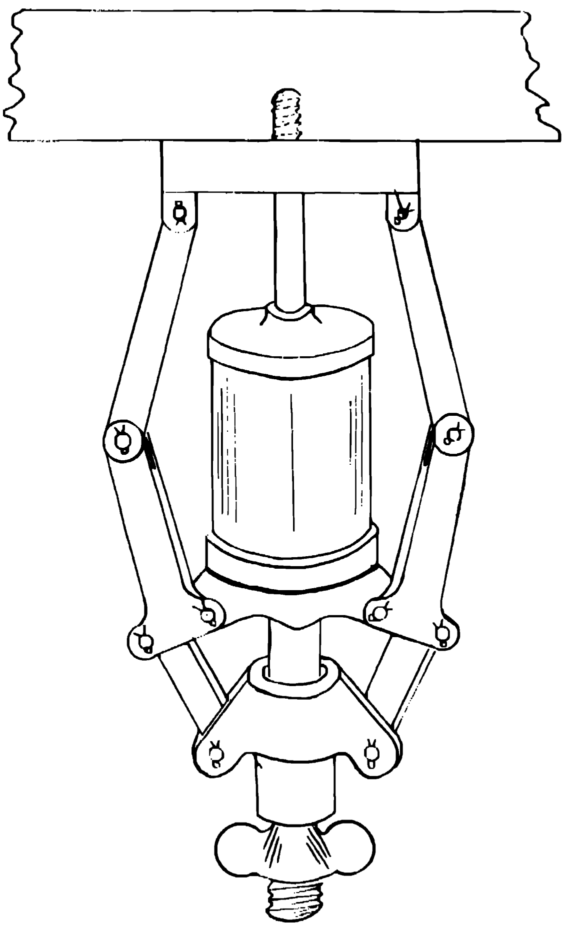


Fig. 144.—Toggle die-cushion attachment.

Besides pneumatic and hydro-pneumatic die-cushions, there are several mechanical attachments for regulating the pressure in press work.

Toggle Pressure Machine.—This attachment, which is shown in Fig. 144, is particularly suitable for use with combination dies. It is constructed to give uniform pressure on the blank, increasing the efficiency of the tools being used by minimising the stress on the material being worked, thus reducing the possibility of crinkles and fractures, and also adding considerably to the life of the tool. The idea of the toggle mechanism, which will be understood from a study of the illustration, is to reduce the amount of compression on the spring or rubber by the application of leverage. This reduction of compression makes possible the manufacture of deep shells and often reduces the number of operations required.

Rack and Cam Attachment.—This is another device for regulating and prolonging equalisation of the buffer pressure. The machine (Fig. 145) is screwed on to the underside of the tool, the pressure pins being extended through the bottom, so as to come into contact with the buffer platform. When the die is depressed, there is a downward movement of the lower plate against the spring pressure caused by the action of the cams swivelling whilst being in mesh with the rack. The amount of pressure needed can be regulated by the hand nut at the bottom of the spindle.

Suitable Speeds for Presswork.—It is essential that great attention should be paid to the question of the most suitable speeds for presswork. Tools designed in the drawing office are usually planned for certain presses, this information being sometimes noted on the drawing, but the idea being merely to produce a tool capable of going under the ram when fully extended, which is called the " shut height." The particular press may, however, be very rapid or very slow in action. The correct values of the speed, for producing the article required, are then left to the practical man in the shop, either the try-out man, the press-room foreman, or the press setter. Presses of the self-contained type, having their own motor attached, usually have the necessary information worked out on a scientific basis supplied by the makers, with revolutions, weight and size of flywheel, etc., from which the calculations can be made for weight of blow.

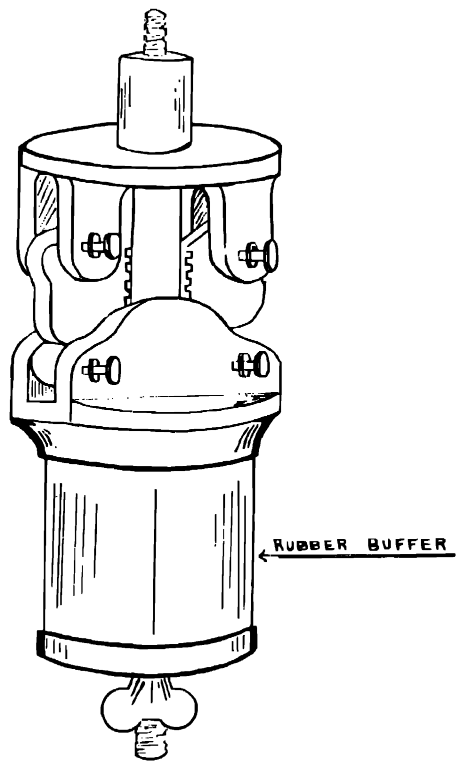


Fig. 145.—A further die-cushion attachment—cam type.

With small press tools for brass, steel, spring nickel, etc., the presses require to be fast, especially if they are of the blank and pierce variety carrying very small piercing punches, not less than 250 strokes per minute being required, or trouble will occur due to the thin punches not having sufficient impetus to pierce the metal, and so they will bend and snap.

It is obvious that the size of the press governs to a great extent the speed at which it can move, but the area of the blank or draw, as well as the gauge of the material being worked, plays a most important part. Drawing operations require slow-moving presses, to give the metal being drawn sufficient time to balance and settle to its structural alterations, as well as to minimise the strain, which would otherwise result in fracture. The question of speed in relation to heat generated by friction, especially where cooling lubricants are not available in sufficient quantities, must also be taken into consideration.

Blanking tools with a shear on the die or punch always produce a cleaner component in a slow-moving press, which will be generally understood when one thinks of the cutting action of scissors. Bending tools are much more profitable when used in slow-moving presses of about sixty

strokes per minute, especially on the heavier-gauge materials of $\frac{1}{8}$ inch or over, fractures being less frequent and the bends cleaner and more uniform.

Unfortunately the press setter is often greatly handicapped in respect of operating speeds. He may get a tool to produce a certain job, and with his experience he at once realises the speed at which that tool should be worked, but the press he has available, to use a trade term, fails to "knock the component out" and jams. His only alternative is to put the tool in a faster-moving press to gain impetus and weight and this is often against his better judgment.

The following information on the subject of press jamming should prove to be of value. In a blanking tool, if, upon being set, the press is incapable of cutting the material and stops, it can be usually overcome by pulling the flywheel round and "bumping" it, until the punch passes through the material, when the tool can be transferred to another press. But in the case of a bending or forming tool, when the press is set the punch usually "bottoms." Now if the press is set too deep by a considerable amount, the ram will just descend and stop! But if this extra depth is a small amount, say about ·010 inch, the crank will spring and the press stop with the component or tool underneath it. Exactly the same thing occurs if two blanks are put into a forming tool in error. Perhaps it will be sufficient to remark as indicating the trouble which ensues that it sometimes takes two men twelve hours to get the press working again.

Lubrication.—One of the most important things which has to be considered in the fabrication of metal parts, especially where drawing takes place, is the necessity for securing adequate lubrication of the tools and material. For hand-operated and slow-speed machine presses, lubrication is not of much importance, and it usually appears sufficient to apply any form of lubricant at irregular intervals, but high-speed machines require a copious supply of the right kind of lubricant continuously in order to reduce friction. The usual practice of placing large quantities of one form of lubricant in the press-room and using it for all purposes, such as drawing, forming, cutting, etc., is not only very wrong, but very extravagant. To choose the lubricant of the right kind is a matter of intelligence and one of the principal problems in relation to speed and maintenance. The kind of lubrication that has to be employed is what is termed a coolant, and one that does not break down and allow actual contact between the metal of the tool or component, as it is this which will cause rapid wear of the tool being used as well as scoring of the component.

The ideal condition is to have a film of lubricant between the tool and the piece-part, but the attainment of this is an extremely difficult matter, and although many experts have spent much time and thought on the subject, information is still far from definite and complete. One of the most commonly used lubricants is soap solution, which is best used hot, as it has been discovered that its effect is then superior to when it is cold.

This liquid acts principally as a coolant, but it also has lubricating qualities. Sometimes considerable advantage is gained by the addition of an oil, either animal or vegetable, thereby forming an emulsion ; a commonly used and much-favoured mixture being : water, 10 gallons ; soap, $2\frac{1}{2}$ lb. ; soluble oils, $2\frac{1}{2}$ lb.

One of the best-known lubricants for cutting and punching, and one that is often recommended for use when drawing copper alloy or brass, is lard oil.

For drawing steel a good lubricant and one recommended by many men of experience is : 25% tallow, 25% flaked graphite, and 50% lard oil. This composition is used hot and the metal run through it before entering the tool. For heavy steel drawing, another mixture which has found favour is : 1 lb. white lead, 1 quart shale oil, $\frac{1}{4}$ lb. black lead, the black lead being previously mixed with a pint of water before adding the other materials.

A drawing lubricant for heavy steel shells has been found in a mixture of lard oil and precipitated chalk. These two ingredients are thoroughly mixed together and afterwards allowed to stand, a jelly-like substance being thus formed. It should be mixed according to the gauge of steel being drawn, *i.e.* the heavier the material, the thicker the jelly.

The application of metal polish to the surface of metal strip is known to be of great assistance in the prevention of fouling, also zinc oxide and graphite have been used with success.

The fouling of tools, which is mostly due to the corrosion of metal particles on the die, and often on the punch, is a very important matter and frequently proves a costly obstacle, as it usually necessitates the removal and " taking down " of the tools and re-setting after cleaning. Metals vary considerably in their tendency to foul, and it has often been found advantageous to have those parts of tools that make contact plated with chromium.

Of the copper-alloy group, brass is the most important for drawing operations, because its fouling tendencies are of the lowest, allowing for long uninterrupted periods of economical production.

Drawing Soft Metals.—Aluminium and zinc are more plastic than brass or steel, inasmuch that they will accept considerably more deformation without tearing or cracking, and also can be given a greater succession of drawing operations without the necessity for frequent annealing.

The ductility of all metals is governed by their mechanical properties, and different tempers of the same alloy will have varying workable limitations. Aluminium has a much higher coefficient of friction than brass or steel, so that precautions must be taken when drawing it to reduce resistance as much as possible. With this end in view, all contact surfaces of dies and pressure devices require to be in a smooth, polished condition and greater attention paid to efficient lubrication. The pressure applied to hold the blank should be reduced to the minimum, in most cases just sufficient to keep the sheet flat.

Lubricant for Aluminium.—For drawing operations on aluminium fabrications, low-grade petroleum jelly is often used. Paraffin oil is sometimes applied, and is very valuable to prevent the tool from becoming "loaded," resultant from the abrasive action of the metal. Cylinder oil can also be used when working this metal, being found by many practical operators to give the greatest satisfaction.

CHAPTER 7

DIES FOR BENDING

THE progress made with the precision bending of metal is on a par with that which has been made with other branches of engineering production. The bending of metal to obtain uniformity of shape is a difficulty which only experience in tool design and the use of scientific principles can overcome satisfactorily. After the blacksmith's or wrought-iron worker's method of producing a predetermined shape, which was usually to a chalk line drawn on the anvil, came the bending blocks, and of course these are still used in a great many industries to-day, especially on aircraft work, where the number of components called for may be only "one per machine" and it is therefore usually deemed unnecessary to make a precision press bending tool.

Bending blocks were usually made in several component parts, such as a solid block to maintain the internal shape, side and other plates fitted on pins to form the various radii which were needed to produce the component to requirement. These blocks were held fast in the vice with the sheet metal between them, the sheet being then bent and formed to the required shape with the aid of a heavy rawhide-faced mallet or a lead hammer. Undoubtedly this method was very satisfactory, within a very large margin of limits, on thin material, but it was almost impossible to produce two parts exactly similar, owing to various factors such as the natural springiness of the material being bent which could not be effectively overcome, while unequal distribution of pressure was another of the obstacles to accurate results. Bending blocks were made of mild steel, and if the component being produced had any holes in it, these were of great advantage as pins could be fitted in the bending tools to enter the holes in the component which had been previously drilled, and this would maintain the part in a definite position whilst being bent (Fig. 146).

Plain Bending Tools.—Success is gained by experience in the design of bending tools or, perhaps, one might say that experience is gained by failures in the design of bending tools, as undoubtedly one learns more from failures than from successes. With bending tools, as with most other press tools, in one class of bend the punch plays the most important part, and in another the die is the prominent feature, while in some cases both punch and die have an almost equal right to distinction. In whatever type of tool metal is bent, certain elementary factors must be kept in mind, one of these being that the metal must not be stretched

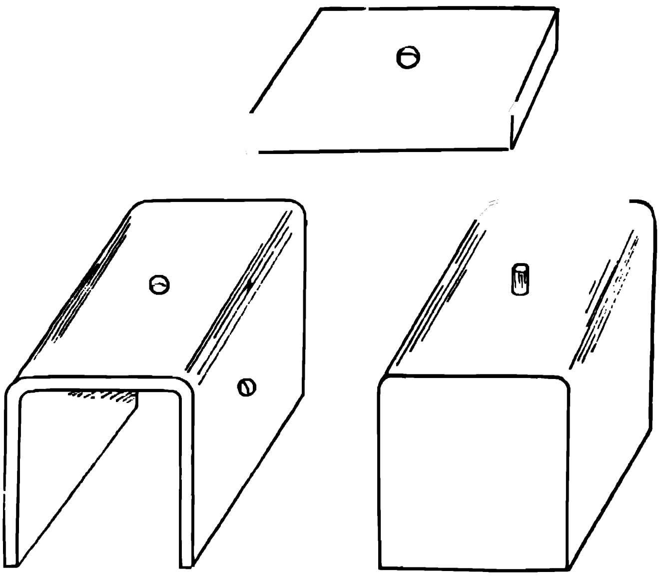


Fig. 146.—Bending blocks, also showing component after bending.

and overstrained, otherwise it becomes weak and liable to break off very easily; another thing to remember is that when material is being bent in a tool made for the purpose, a great amount of distortion is caused by the strain which is almost impossible to recover or "push back" if the material is already trapped. This will, perhaps, be better understood from a study of Fig. 147. It will be quite easy to visualise from this sketch that when the punch starts the downward movement, the material tends to leave the underside of the punch as shown, and when the punch reaches the bottom, owing to the fact of there being a gap between the material and the punch, it is obvious that there is more metal than is required. Hence, the action of the tool is, if possible, to force the surplus metal back up the sides, but this it cannot do for the reason already given. So what really happens is that the metal forms a distorted wavy line in its effort to get rid of the surplus. When the punch is pulled up, instead of the components' arms being at 90° as required, they will both lean in towards each other and the bottom of the bracket will be wider than expected.

To overcome this, the pressure pad was invented. For very light articles, dependent on the area and gauge of material, these tools can be made self-contained, that is, with springs underneath

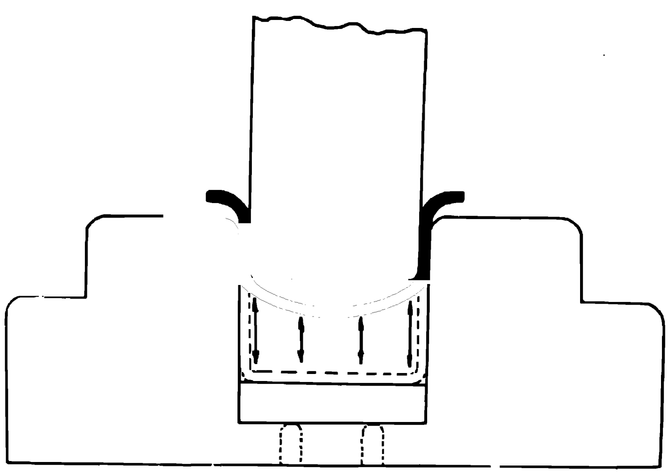


Fig. 147.—Bending tool, showing possible error.

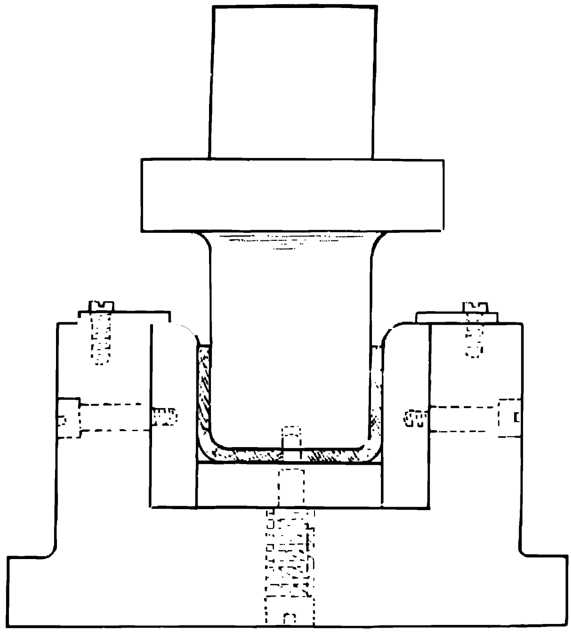


Fig. 148.—Bending tool—component in position.

the pressure pad forming part and parcel of the tool (Fig. 148).

The bolster is usually made of mild steel, and the punch, cheeks, and pressure pad of cast steel, which is afterwards hardened and tempered. The pressure pad is tempered down to a blue colour after hardening as it is liable to crack with the blow at the bottom if it is too hard. The punch is made to the stipulated internal dimension, but the cheeks are left slightly oversize and then ground to suit the material being bent, which in all probability will be in excess of the stipulated size. The complete set of components to make up a tool of this description, including the springs, is shown in Fig. 149.

It is absolutely necessary to keep the metal which is being bent in contact, as far as possible, with the pressure pad to avoid excess metal. Hence, as already explained, with the increase of gauge or thickness of material, we must increase the pressure in proportion, and if it is impossible to exert sufficient pressure by springs contained within the tool, then a large buffer spring or rubber buffer is placed underneath the bolster (Fig. 150).

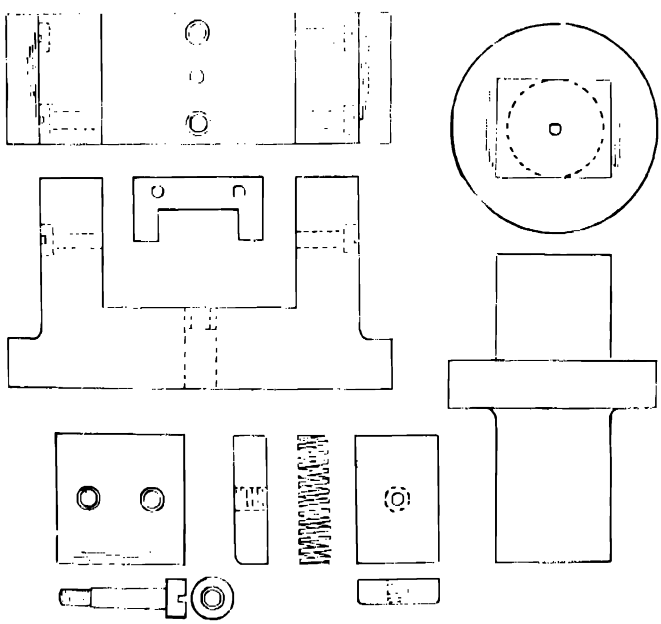


Fig. 149.—Details of a bending tool.

One must not be deceived into thinking that the greater the pressure, the better; indeed it is not so,

especially if bending fairly thick soft metal such as copper, brass, or zinc, as if the pressure on the metal between the punch and pressure pad is excessive, it will have a similar effect as in Fig. 147, not drawing too much metal in, but expanding and lengthening it by compression.

Vee Bending Tools.—Two arms at any given angle are best bent in a vee tool. This is a good class of tool for positive bending, as the flow of metal is even and unrestricted, so that the job is not liable to distortion.

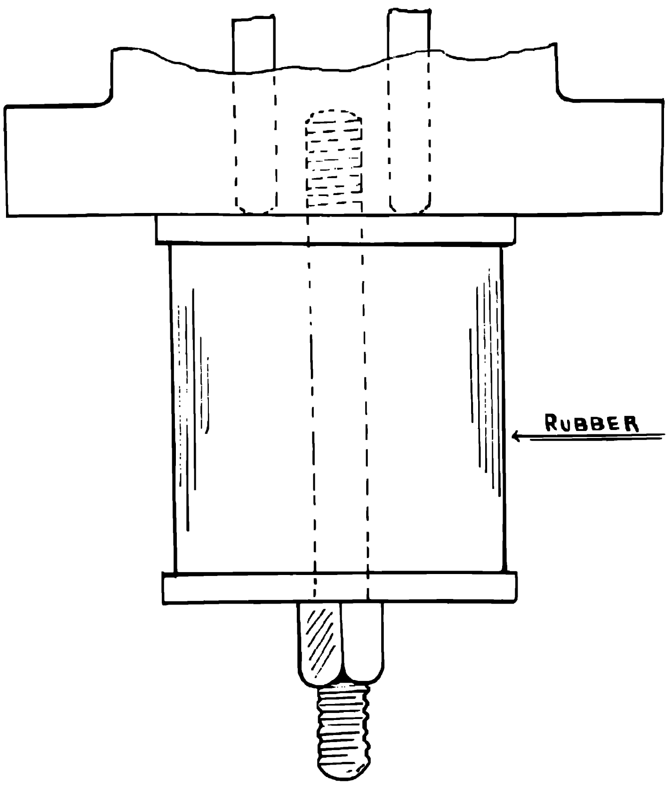


Fig. 150.—Rubber buffer for bending, used when bending heavy-gauge metal.

In many acute bends on thick or springy material, where the angle has to be to some definite figure, the tool has to be constructed to "over-bend" in order to allow for the amount of recovery due to the springiness of the metal being bent. No set rule is observed, but where a bracket has to be at, say, 90°, the simplest way is to make a punch at 89° and a die to correspond, or if very springy material is being used and a considerable recovery is anticipated, then 88°. The reason for this is that if any modification is called for, especially with the die, it is easier to increase than to decrease an angle. If the bend has to be very sharp, the most economical method is to complete it in two operations, with an annealing process in between, as it is not right to expect too much of

metal; and to have breakages occur when the part is put into use, merely shows bad workmanship. The vee tool illustrated in Fig. 151 is in a great many shops made from solid cast steel, but in others it is made from mild steel and skin-hardened in the cyanide bath when completed. The screw holes for the location plates are drilled right through but only tapped at the top, before the tool is hardened, the holes in the location plates are not drilled until finally, that is, after the piece-part has been developed to size. These plates are usually held in position with a tool-makers' clamp, and supported on the hand-press bed with parallel strips, until the final adjustment is made to the length of metal, this being obtained by "trial and error." The tool is then turned over and the holes transferred right through into the location plates by drilling.

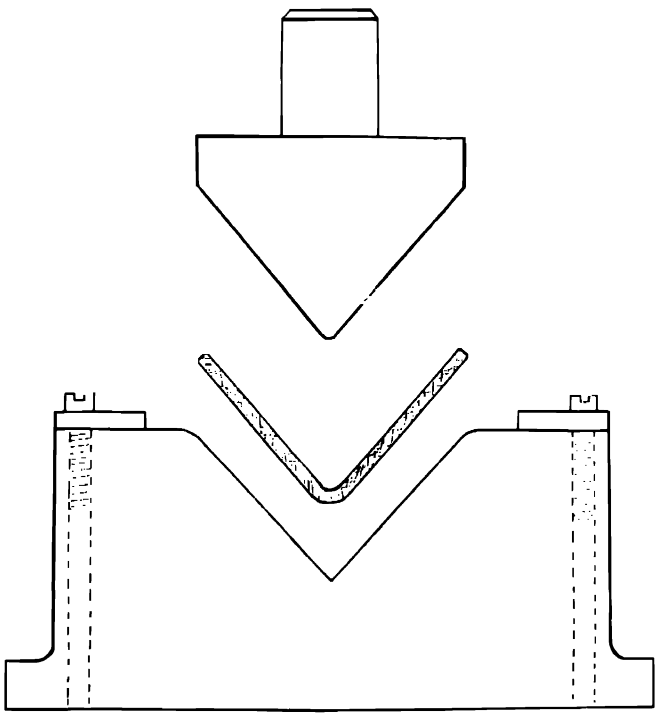
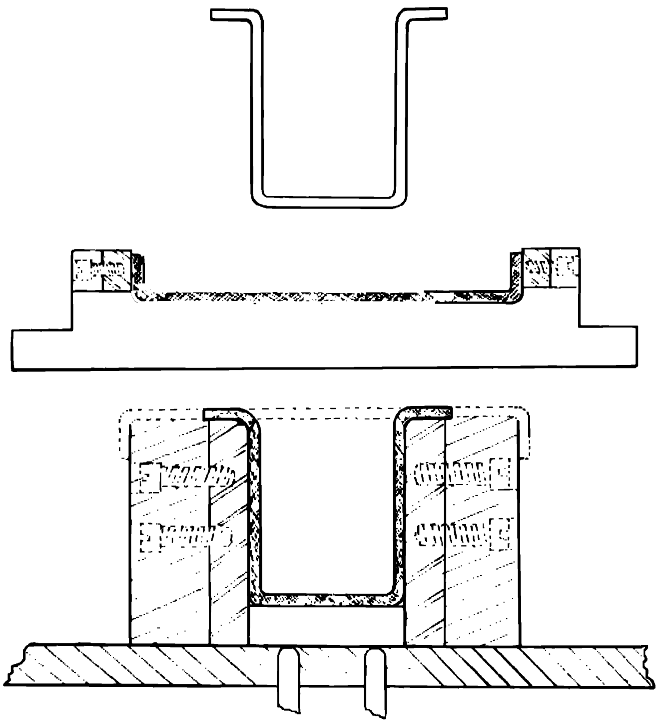


Fig. 151.—Vee bending tool—component in position.

Multiple Bends.—It often happens that several bends are required on one strip of metal in order to form a single component, although, if the material is thin, it can probably be done in one operation. If the metal is of heavy gauge, it is usual to make two or more bends. Simplicity combined with thought, to discover the order of sequence and avoid overstress, is the keynote of efficient bending processes. A short time ago the writer was responsible for the production of an enormous quantity of brackets from $\frac{3}{16} \times 2$-inch soft alloy. They had to be positively square, free from fractures, stretching and thinning had to be avoided, as they had to conform to the specification of one of the Government departments. The radii were down to the lowest limit, *i.e.* the corners had to be as sharp as possible. The job could easily have been done in one operation, excepting for the snag that thinning had to be avoided. The brackets would certainly be checked over with a micrometer, and the thinning in the longest parts of the material would be discovered and quite possibly the job would be rejected in consequence. So, after giving the

matter considerable thought, it was decided that two operations, with positive bends, should be employed. The bends require no development, they cannot be any different, so that to find the exact length it is only the two ends requiring alteration after bending, which is quite a simple matter. In this instance, due to the quantity required, we made both dies and punches of mild steel, with cast-steel cheeks to the bottom tools and corner pieces let into the punch to form the radii, as this is really the only part where any wear takes place. The pressure pads were made from mild steel carburised and case-hardened, as if practicable this is the better way. If they are made from cast steel, they are liable to crack with the sudden jar and distortion (Figs. 152 and 153).



Figs 152 and 153.—Bending a bracket—first and second operations.

Pillar-type Bending Tools.—The foregoing class of bending tool is quite good for many components, especially where each bend is to a certain extent balanced by the main stress being towards the centre line. Should this not occur, and the tendency is, perhaps, for one side of the component to run towards the centre and the opposite side away from it, then different tactics must be employed to retain rigidity and balance of power. Should the component to be bent have a sloping base, it is quite obvious that the pressure applied will be uneven and cause side strain. This can sometimes be overcome by a pilot on the punch to accept the pressure, or one part of this member entering the bottom tool in advance of the bending operation, but each and every job must be designed according to the shape of component, always taking into consideration the thickness of metal to be bent, as quite naturally this will govern the pressure needed. In several large production works where many years of good practical experience has been obtained in handling these operations, pillar-type bending tools are almost invariably used. This is particularly the case if the tool design follows American or Canadian practice

(Fig. 154); it is a very sound idea, as the foundation of the job can be standardised, with a range of sizes, and the possibility of faulty setting is entirely eliminated, which undoubtedly is of considerable importance in bending. It is impossible for the tool gradually to work over, *i.e.* to get out of position by side stress, and uniformity will be maintained throughout. The top and bottom bolsters are composed of cast iron, although sometimes cast steel is used. The pillars of good stout dimensions are constructed of mild steel carburised and case-hardened. It should be noted that cast-steel pillars are not used; they eventually warp as a result of the hardening stresses, and then sometimes cause a seizure. Oilways are recessed in the pillars to minimise friction, when side stress is imposed. The bottom and top tool in this type is usually composed of medium-quality cast steel, screwed and drilled in position after hardening.

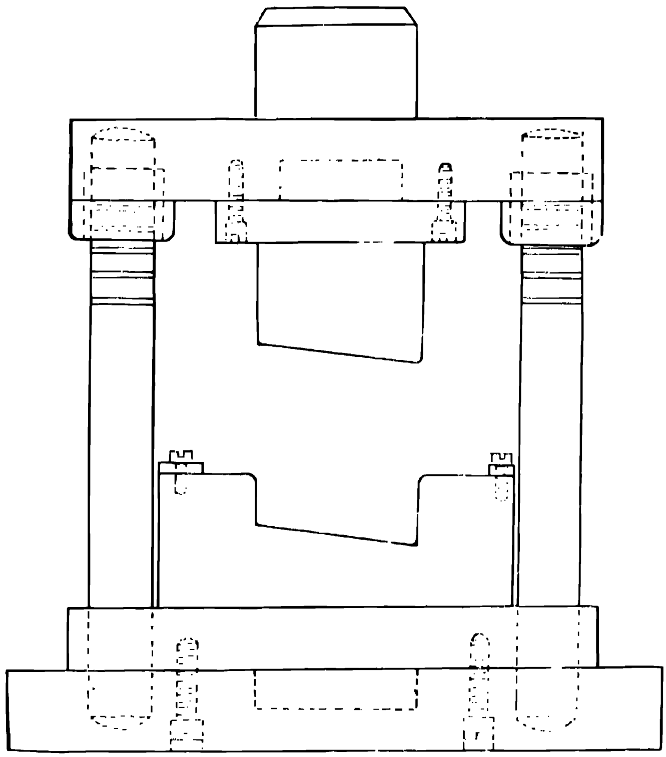


Fig. 154.—Pillar-type bending tool.

To this class of plain bending tool it is unusual to fit any stripper mechanism, as the press can only be operated in single strokes and the piece-part is easy to remove. It is mostly pushed off by the operator with a metal rod, in the case of an inclined press, or pulled off with a hook when a horizontal press is used.

Bending or Forming.—It is very difficult to differentiate at times between the terms "bending" or "forming." If a sheet-metal part is shaped by confining it between a punch and die, and by their combined pressure the shape is directly reproduced, then this can be considered a "forming tool." But if, on the other hand, the action confines itself to bending, as for example, when the punch passes a certain position and drags a lug of the piece-part to a desired angle or closes a gap formed by a previous operation, this should be called a bending tool. It will be realised that in the case of bending tools, not nearly the same amount of

difficulty occurs in finding the development for blank sizes, and in the majority of components calculations made by simple elementary principles will be found to work out correctly. As an example, Fig. 155 shows a tube bent in two operations by simple tools in a hand or fly press.

Pierce-bend Tools.—In many instances it is impossible to bend articles in conjunction with a blanking or piercing operation, in the majority of cases bending being a job apart. It is, however, sometimes possible to make a tool so that various operations may be performed on the same die-block, certain parts of the work being transferred from one section to another as the various operations are completed. In other cases it is often necessary to make several sets of bending tools to complete one particular article. When a stipulated number of components have been bent on the first die, the economical method is to have the tool for the subsequent operation set up in the adjacent press, and so on to the completion. If a highly paid experienced operator is working on the first press and less experienced workers are employed for the following operations, the latter will be continually struggling to keep up with the production of the first press in order to prevent a "pile-up," and this should be avoided if possible. Pierce-bend tools are a standard product in a great many tool-rooms and fulfil a very useful purpose. The only difficulty about them is the development of the piece-part, to ensure the holes coming in the right position, as the importance of holes cannot be overlooked. For assembly purposes of wireless sets, telephone receivers, electrical instruments, etc., holes are useless unless they are within a tolerance error of ·002 inch.

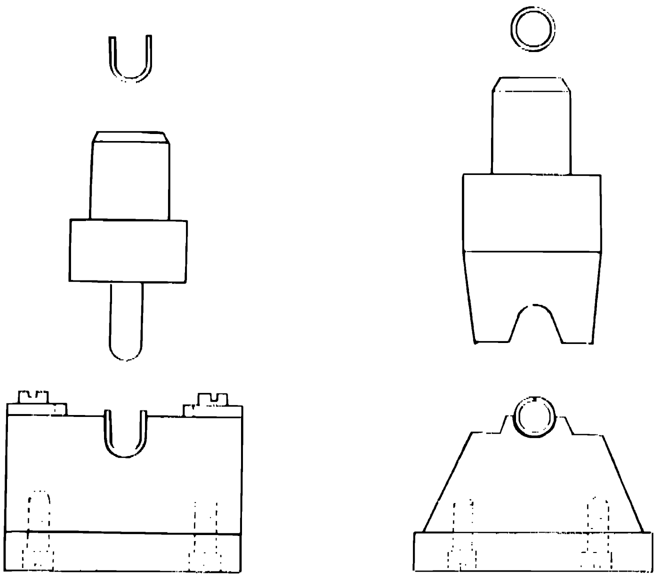


Fig. 155.—Tools for bending a small tube.

The little tool illustrated in Fig. 156 makes the small bracket shown, in one operation, and to get the development, the tool is made up to the previously calculated dimensions, the die being left soft. The piercing holes in the die and also the holes for punches are left out. The hole that accepts the stop is placed a little farther back than the calculation demands, as it is an easy matter to make various other stops of increased size. The cutting and forming punch is hardened and tempered, as this member

will require no change. The material these brackets are made from is standard-width brass strip, which can easily be cut on the soft die without causing damage. A rough figure is arrived at, which should give the position of the two holes before bending, and these are then drilled in the strip, the holes being then checked over for any error and the results carefully noted. The strip is now fed into the tool and bent, after which it is checked up to the piece-part drawing, and the holes either placed wider apart or nearer together, until the correct development is found. The piercing holes are then bored in the die and transferred through into the punch mounting. The die is then hardened, as very little, if any, distortion is contemplated with the modern tool steel, and even if there is two-thousandths of an inch shrinkage it is of no importance, as the dowels which retain the die on the bolster are not transferred until finally.

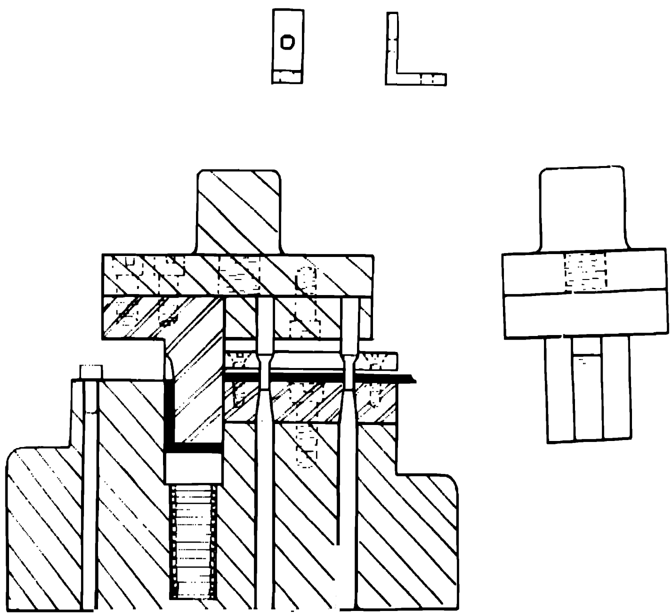


Fig. 156.—Pierce and bend tools—making a small bracket.

Blank and Bend Dies.—When bending articles of many shapes, it is usually necessary to make the tool so that certain sections are bent before others. Should an attempt be made to make the tools solid in order to complete the job at one blow, owing to the material being held at certain spots, it would have to stretch to conform to the die form, and this should be avoided where possible. Where piece-parts are produced from very soft material, this is sometimes possible, but, as a matter of course, the metal will be thinner and narrower where stretched.

Blank and bend dies are made in considerable quantities, which punch the part from the stock and bend it to the required shape by the blanking punch, one tool performing the dual operation. Usually it is advisable to blank the part in one operation and bend it in another, but there are many instances where the two operations can be performed at one blow with satisfaction, thereby reducing the cost considerably. Besides an appreciable saving by eliminating one operation, there is also the cost of more than one tool to be taken into consideration.

Convex and concave spring washers, which are extensively used in gun making and other work, can be made in very simple tools with a centre hole or not, as the case may be. As will be seen from Fig. 157, the washer is first pierced, then cut and carried down by the blanking punch ; pressed into shape on the spring pressure platform, and upon the return journey knocked off by the spring trigger, which is also operated by the blanking punch. One thing must be particularly observed and allowed for in the construction of this tool—the piercing punch must not, under any consideration, come into operation until the main punch has severed the previous washer, as owing to the form being otherwise than flat, the material is pulled in towards the blanking punch to make up the extra amount needed for the form. This strain would be imposed on the piercing punch, if it had already entered the metal, and it would probably break off or make a very bad hole, also the die and punch would soon wear away, being continually thrown out of alignment.

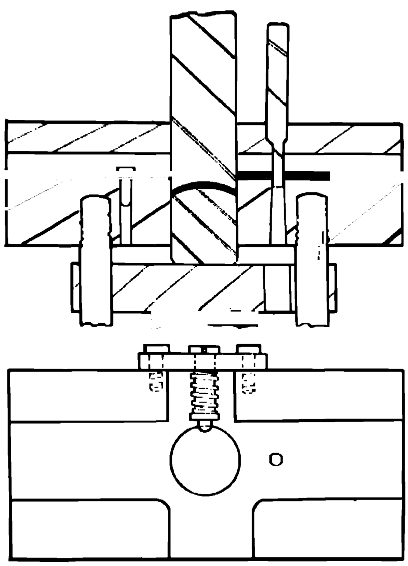


Fig. 157.—Pierce and blank tool for spring washer.

Right-angle Bends.—Many parts can be bent up from the strip with as many as four distinct right-angle bends in a standard bending tool, by simply having removable locations which can be replaced by others. The material is cut off to length and one bend made on all the components called for, the location is changed by the press setter, and a further bend made and so on, until the whole of the operations are complete. These standard bending tools are usually made from good-quality cast steel, hardened and tempered, which will prolong their life and also enable them to retain their shape and form for an indefinite period.

Location plates are best made from gauge plate, which is flat silver steel, and these are also hardened and tempered. Many tool-makers fit tapered dowels, shouldered down at the top end and riveted into the plates. Tapered holes are reamered in the bolster to match up with these dowels, which are then toughened up. This allows the plates to be changed easily and without being knocked about. It is preferable to make the upper tool with the mounting made by the punch passing through the plate, a good tight fit, burred over and backed by a top plate or punch pad, as this method adds stability to the tool, upon which there is usually considerable side stress. The first operation consists of laying a strip

of metal, previously cut to length, between the location plates; the punch then descends and forms one right-angle bend, leaving the other end of the material straight, as in Fig. 158 A; it is then turned round and using the same location, the other end is bent up; the location plates are then changed, and the remaining two operations completed, B. Where there is sufficient gap, so that the material does not foul the punch when the bend is made, the uses to which this simple tool can be put are unlimited.

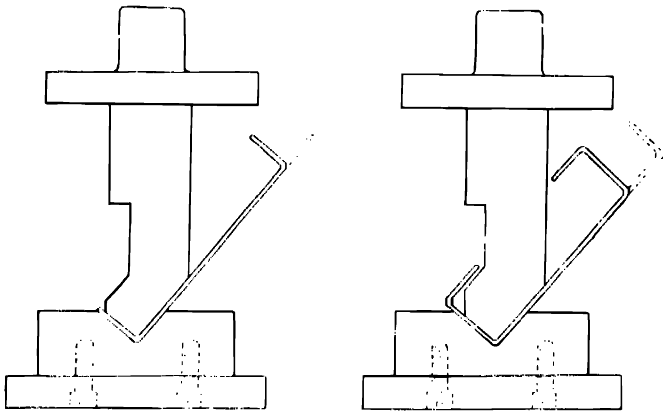


Fig. 158.—Right-angle bend—first and second operation.

Cam Tools.—In the bending of some components, unless the punch descends centrally on to the material, equalising the pressure, there is always a tendency to drive the punch away from the work and the work away from the tool. There are several methods adopted for overcoming this; one is by the use of a spring pressure pad, which descends in advance of the bending punch and traps the metal by holding it very tightly. Another is the cam method, which it is considered preferable to springs, unless for thin material, as there is always a chance of movement with spring pressure, and the weight needed to hold a part, whilst being bent, is considerable. With the cam action, one part of the tool is in the shape of a leg with a set to it, and this descends prior to the punch, closing one block towards another, as in a vice. It is an idea which is used on many tools for various mechanical operations, such as—bending, forming, staking, etc., and some tool designers develop a leaning towards cam tools which is sometimes annoying if there are simpler and better methods available. Fig. 159 shows the tool with the component after bending. It will be noticed that the short end of this piece-part is flattened, and as the bending punch performs this also, it will be apparant that the part requires to be held very firmly.

Loop Bending Tools.—Another type of small bending tool which is suitable for use with a fly or hand press is the loop bending tool which is positive and, excepting for a disappearing location, is springless. The construction of the tool is very simple, and if light brass or mild steel is used as stock, it will form a complete loop, as, for example, on a hinge. It is rigid and stable, and is so designed that it holds the punch towards the material, and the metal towards the tool (Fig. 160). If it is made to limits and the material is up to size, when the punch is being withdrawn the

friction will cause the piece-part to be pulled out of the tool. It is possible to use it on a small power press, but extremely dangerous, as all open tools of this description are.

In connection with the foregoing group of operations, the outstanding technical point to be considered is the hardness of the strip or sheet metal, otherwise the "temper" of the material. When selecting metal, the properties chosen should be such that the bending operations can be made without fear of cracks or splits. The principles underlying the bending processes are usually very simple, but in some production

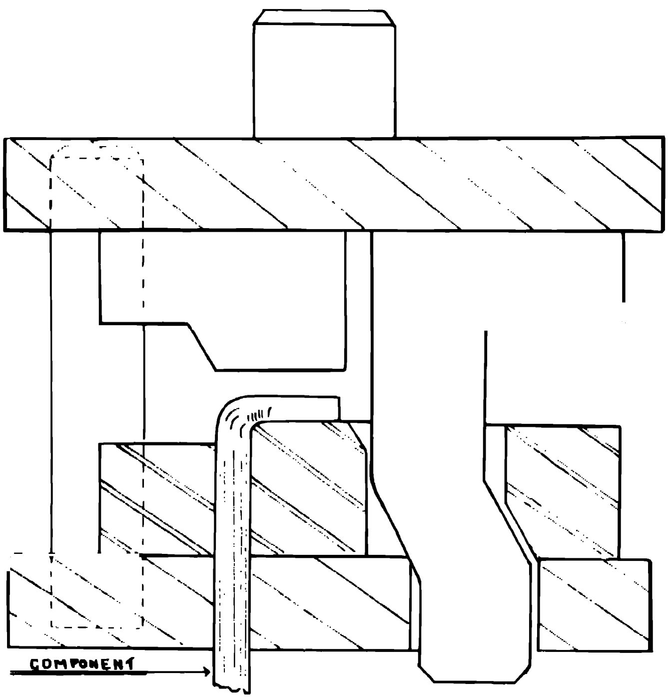


Fig. 159.—Example of a cam tool—bend and flatten.

factories the machines employed to carry them out are often very elaborate and complicated.

Drawing and Rolling Strip.—Where long lengths of various-shaped sections are required, they are produced by drawing through a die, designed for the purpose by means of a drawbench, this being often the most economical and expedient method. In the production of long formed sections as, for example, architectural purposes, a modification of this process is employed. Often, when great quantities of bent section are required, they are produced by rolling. The rollers are machined to reproduce the shape required by means of grooves, radii, etc., and the sheet metal passed through them, but as this is a very costly procedure it is strictly limited in application.

Whether certain sections can be produced from the solid by extrusion, or rolled from strip, depends largely upon the dimensions, as these production processes have the usual economic limitations. Where the gauge of metal does not exceed $\frac{1}{16}$ inch, it is usually decided to manufacture from strip.

Springs and kindred articles which are made from hard rolled or drawn strip metal, bent in press tools, should be arranged, if possible, so that the most abrupt bends are at right angles to the grain of metal employed, because it has been found that material can be bent with more certainty opposite to the direction in which it has been rolled, than with that direction. The radius of all bends should be made as large as circumstances will allow, in order to reduce the causes of weakness such as fractures and surface cracks. Much valuable information and data have been compiled regarding the hardiness and bending properties of certain materials by Straw, Helfrick & Frischrupp (*Amer. Inst. Met. Eng.*) and G. R. Gohn (*Amer. Soc. Test Mat.*, 1936).

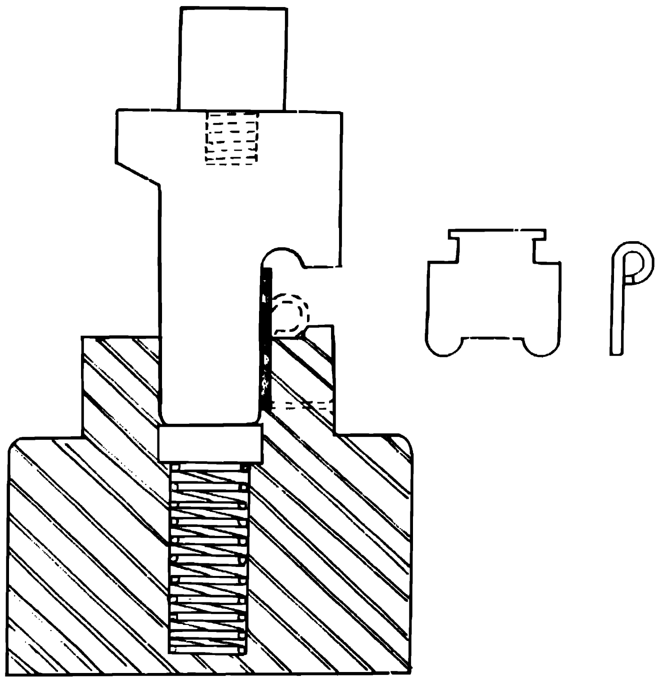


Fig. 160. Tool for forming loop in one operation.

Piercing Dies.—The piercing of holes is governed by several factors, which have to be seriously considered where thin metal is concerned. The design of the tool plays a very important part, as also does the hardness of metal to be pierced, but it is generally safe to limit the lowest margin of piercing to a hole of diameter equal to thickness of material. It is quite possible to pierce holes of diameter one-half the stock thickness, in tools specially designed for the purpose, such as compound tools which have already been explained, because the piercing punches are supported all the way down. Moreover, the piercing takes place at the moment of blanking, so that the material is rigid, also it is a trick of the tool-maker to limit the length of the small piercing punches to minus approximately one-half the thickness of the material being pierced; this also helps towards rigidity and alignment, which are essential with small holes.

The practice adopted by many leading firms is that all holes are pierced if the diameter is not less than one and a half times the gauge of metal, smaller holes than this being drilled. This keeps on the safe side and does away with needless and costly experimenting.

The choice of material for piercing punches is another important matter. Silver steel is used extensively for punches which come within ordinary or safe limits, and if the heat treatment is carried out to the manufacturer's specification, it will do the job admirably. Many steel producers market special material for punches (The Ford Motor Co., Ltd., make their own), and one of the best for fine piercings is known as " Van Tapp."

In Fig. 161 is shown an ordinary plain piercing tool. The die is sometimes made solid from cast steel, but often from mild steel with hardened-steel bushes pressed in, and this appears to be simpler and more economical. The amount of die clearance which gives the best results has been found by practical experience to be equal to half as much again as that given to a blanking die, *viz.* one and a half thousandths (·0015 inch) for every thirty thousandths (·030 inch) thickness of stock. Punches are sometimes made parallel, a tight fit in the punch plate and just burred over at the top end; in such cases a hardened backing plate is fitted between the two plates, to avoid the punch digging into the punch pad. In other instances the punches are made in steps with a head, as in the illustration, and are usually ground to size after hardening. One very important fact should be carefully noted, *i.e.* that end of the punch which pierces the material should be perfectly parallel, as if it is a fraction larger at the bottom end, in the action of stripping the punch will be dragged off.

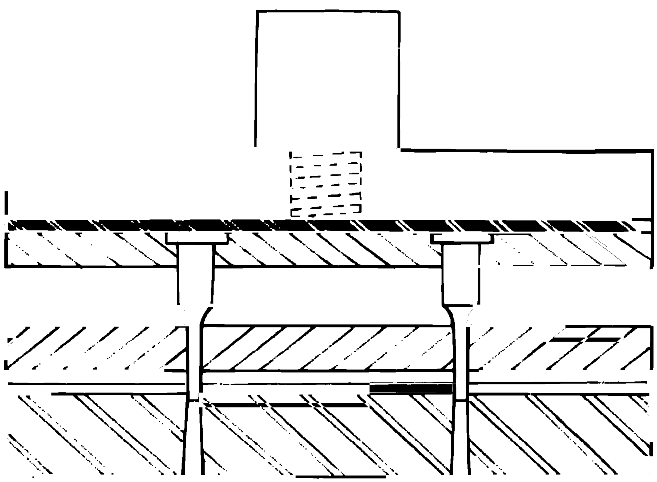


Fig. 161.—A plain standard piercing tool.

If the punch and die are properly constructed with the correct amount of die clearance, the hole will always conform to the size of the punch; but when the die becomes worn and the hole in it becomes larger, then the punch, instead of being able to pierce a clean hole, is allowed to force a certain amount of metal down between it and the die, which will then cause a distorted and larger hole. In some cases, failure to pierce hard and heavy material is due to buckling of the punches, especially when these are not hardened all the way down.

It is a common practice when punching holes in heavy material, to alter the shape of the punch so as to form a shear (Fig. 162). This answers two valuable purposes: first, it does not require such a heavy blow to force the punch through the material, and, second, the punch has a tendency to centralise, instead of being forced out of alignment to the die by distortion. Some designers favour a wedge shape, others prefer three flat sides forming a pyramid, or four flat sides, this being termed "sugar loaf."

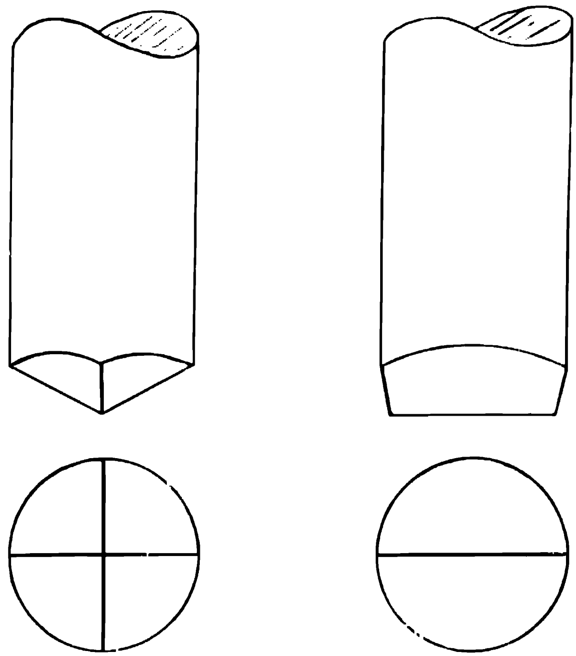


Fig. 162.—Piercing punches constructed with shear for heavy material.

Great trouble is experienced at times by the pierced slugs, which, instead of passing right through the die, have a tendency to return out of the die face. This does not usually occur when a die is new, but immediately it begins to show any signs of wear. There are several distinct reasons for this fault, which only experience can teach, the first being that the die or punch may be magnetic, as a result of being in contact with the grinding machine; secondly, the inside taper of the die may have a slight bump in it, causing an uneven piling of the slugs as they pass down. This, with the aid of lubrication, tends to form an air lock, thus returning the top slugs to the surface. Another reason is that the die may not be sufficiently hard so that it very soon becomes *bell mouthed*, and this will always be a source of trouble. A further reason which occurs in pierce and blank tools, mostly of the washer variety, is that the amount of metal forming the wall cannot stand up to the blanking operation, and collapses on the hole, making the piece-part diameter less than the die opening, thereby allowing them to return. Although in the modern practice of tool-making the die draught is carried right to the die face, where this trouble is liable to occur it is an advantage to leave a "land," or parallel part to the die opening, of about one-fourth the depth (Fig. 163).

Quantity Piercing.—Where very large quantities of any one component have to be pierced, owing to the fact that punches and die must always have sharp edges, it obviously tends to hold up production if the tool must be taken down, re-ground, and then re-set in the press again. In several factories this difficulty has been overcome by designing a

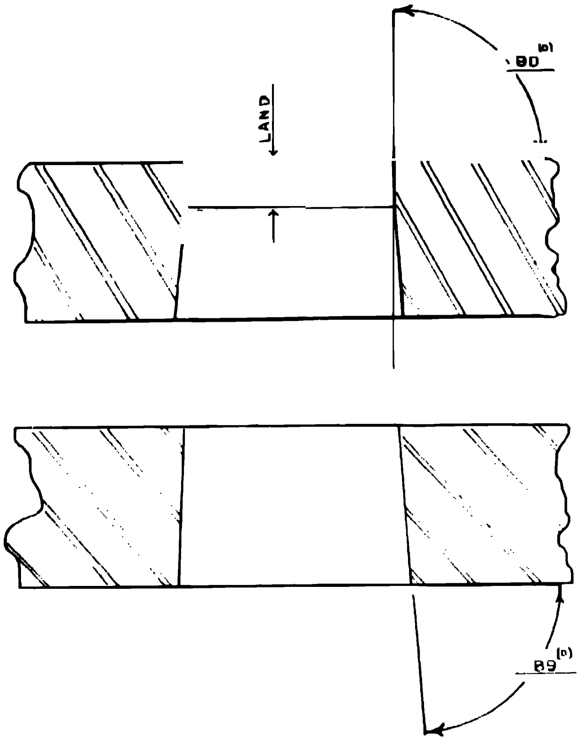


Fig. 163.—Example of a die showing "land."

multiple piercing tool, to do a single piercing job. This may appear a rather costly procedure, but it has proved very economical in the long run, and reduces the "hold-up" time very considerably. Actually, a tool is constructed which is in fact a group of facsimile tools, but all made in one, so that in operation the work is merely distributed between all the punches until the whole of them require re-grinding.

Locations.—It is very essential when piercing holes in small components that the locations should be such that they definitely position the piece-part. With small piercing tools these usually take the form of a nest cut out of a thin plate, which accepts the blank easily, but does not allow any movement. This, although necessary, proves at times to be a great disadvantage, as the component, after having been pierced and stripped off the punches, drops back into the location plate. This can be successfully overcome by fitting a flat spring "knock-out." This little accessory is screwed to the back of the piercing tool, and is composed of a piece of flat spring with a steel pin riveted into one end (Fig. 164). When the piercing has been completed and the punches are ascending in the act of stripping but before reaching the stripper plate, the piece-part comes into contact with the "knock-out,"

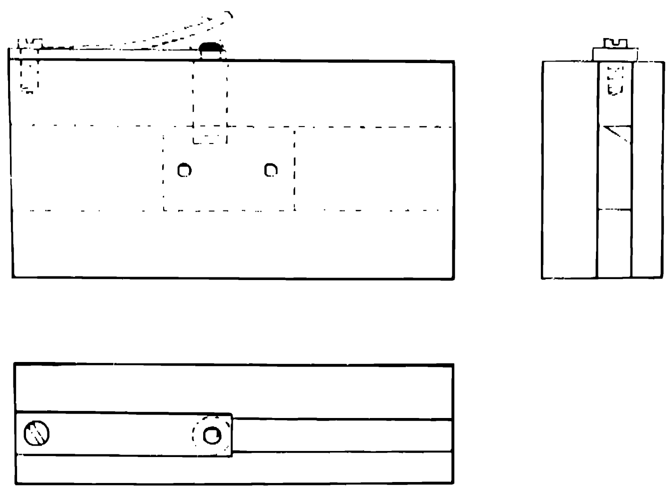


Fig. 164.—Piercing tool with a spring "knock-out."

which is forced back against the spring pressure, until the punches are totally withdrawn, when the component will fly out of the tool.

When piercing or stripping a piece-part which has already been bent or formed, it is very important that the die and also the stripper should conform to the contour of the component, to obviate the possibility of the pressure, when exerted, causing distortion. It often occurs that holes have to be pierced in the outer rim of a shell. If the die is made in the form of a horizontal mandrel, with the die opening vertical or at right angles, the punch must be shaped to conform to the outer radius of the part being pierced, or in other words, the radius of the die plus the gauge of metal.

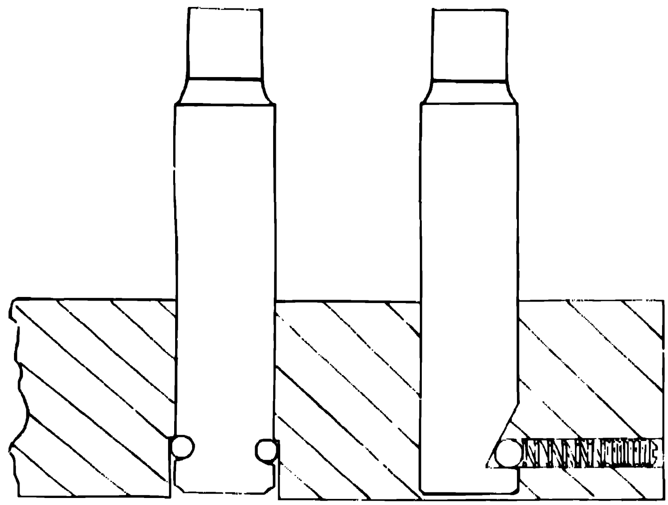


Fig. 165.—Two methods of retaining punches.

In very heavy piercing, the base of the punch is liable to expand and burr up; it then becomes a potential source of danger, tending to bursting the casting; moreover, it is extremely difficult to remove for renewal. This trouble is forestalled by having the bottom end of the punch smaller in diameter than the hole to receive it, retaining it in position by means of a split collar, or by a ball as shown in Fig. 165.

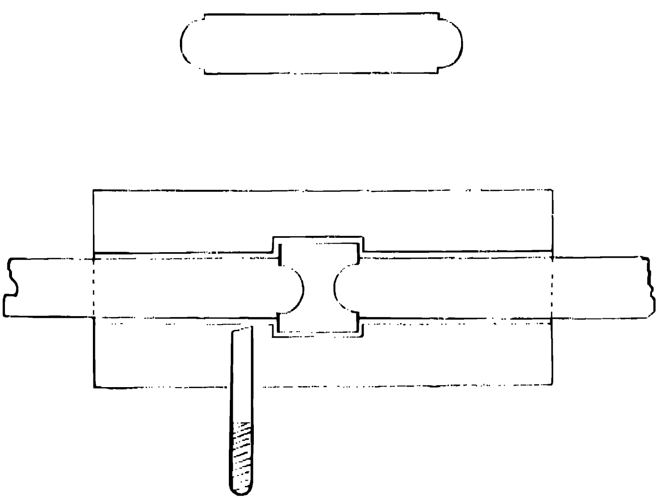


Fig. 166.—Strip-notching tool, showing component.

Notching Tools.—This is merely another name given to blanking or piercing dies, the only difference being that the piece that is blanked or pierced out becomes the scrap, and the other part becomes the product. In the piece-part shown in Fig. 166, the action is exactly the same as in a

blanking tool. There is no side stress, and the punch directly severs the strip and makes two components at a blow, excepting the first one, the position of the material being usually governed by a finger stop. A certain amount of metal is wasted to allow the punch to cut on both sides, otherwise the punch would be thrown over and, in so doing, damage the die.

Where a notching punch only cuts on one side of its face, the other side or back must be supported either by having the punch ground away, so that one part of the punch enters in advance of the other, or by having a step on the die face to act as a stop to the punch when it strikes the material. Both methods of support are frequently used in the construction of these small tools, but the former is usually preferred as it mostly works better. The punch is made to fit the die as in a blanking tool, and after hardening and tempering, one part of the punch is ground away, leaving a leg. On a press with $\frac{1}{2}$-inch stroke, this is left $\frac{5}{8}$ inch long so that just over $\frac{1}{8}$ inch is continually left in the die; the stock is then fed back to this, which then acts as a stop (Fig. 167). In the cutting up of material, when rectangular pieces are required to a definite size, or within ·002 inch, they are usually blanked out. Unfortunately this method causes a certain amount of metal to be wasted between each blank and also a margin each side. For this particular job, a notching tool can be used to great advantage with very little waste, excepting the narrow strip on each side.

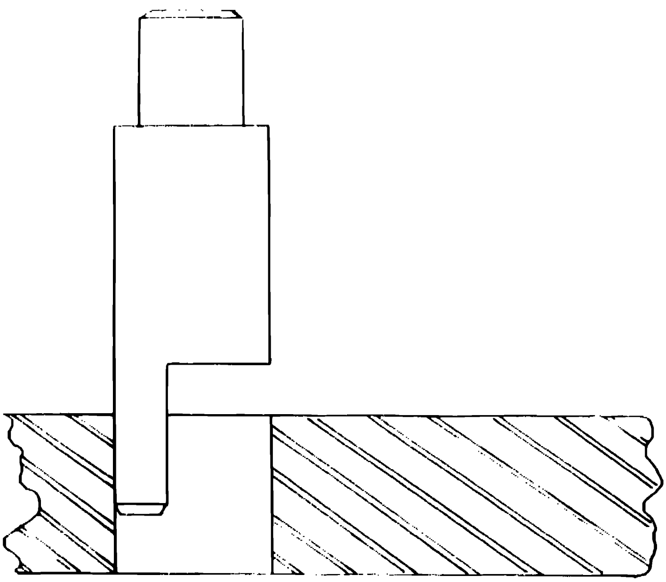


Fig. 167.—Notching tool supported punch type.

Embossing Dies.—Coining and embossing are very similar in many respects. Coining as a method of fabrication is now being more extensively used, as engineers have discovered that a great deal of machining can be eliminated by the efficient use of coining dies. These require special presses, as the pressure needed is considerably more than in ordinary press operation. In many examples of motor components, rough drop forgings are produced, and instead of being machined as previously, they are brought to perfection by a series of coining operations

with the requisite dies. The pressure required is mainly governed by the depth of embossing, and also by the temper and resistance of the material employed. In some instances pressures equal to 100 tons per square inch are required in order to obtain sufficiently sharp impressions. For the production of coins, latch keys, etc., blanks are usually struck with a standard blanking tool from the strip, these are then annealed and afterwards cleaned before being fed into the embossing tool.

Embossing dies are mostly made by the hobbing process as in the case of small tools, and by the die-sinking method in the case of the larger sizes. The type of hob employed is usually fairly easy to make because the pattern stands out in bold relief. Hobs are made from good-quality tool steel, the face being turned and polished and afterwards coloured with a material which allows the embossing design to be traced upon it. The material is then milled away round the outer edge in the die-sinking machine, until only the pattern is left. The raised surface is now finished off with chisels, files, and graving tools, and afterwards hardened and tempered. The die-block is marked off in the same way, the pattern being sunk in to the desired depth by milling tools. The top tool is now located in the recessed portion and pressed in by the hydraulic ram or under the drop hammer. Where the quantity of parts to be produced allows the expenditure, the hob is retained as a master, otherwise it is used as the top tool and the recessing of the female die, opened up, to allow for the metal thickness, before being hardened and tempered.

Embossing dies are essentially to form a pattern in relief, such as letters or an ornamental design on the surface of metal and other materials. Embossing is entirely different from forming, as the impressions to be transferred are mostly very shallow, whereas a forming die is to produce the necessary shape to the component. The lettering, trade marks, decorative designs on all kinds of sheet metal, boxes, cans, domestic utensils, etc., are produced with embossing dies. With a coining die, the impression is usually recessed on both top and bottom tool, but with an embossing die it is composed of male and female members. Dies are often designed to blank, form, and emboss in one operation, and can be double action, triple action, and multiple action, according to the job and presses available. There is local stretching, as well as compression of the material in all embossing operations, and this must be allowed for. The amount of stretching depends on the size and height of the raised pattern, and on occasions much experimenting has to be done to get the metal to accept the design without splitting or cracking ; every problem has its limitations, and the design must be considered in conjunction with the material to be embossed. Sharp corners should be avoided as far as possible, except where the flow of metal is in one line, so that there is no clashing in the direction of stretch of the material. Coining operations are usually performed in knuckle-joint presses, which on account of the class of work they do are often called "coining" presses. The large types are geared and very strong tie rods take the enormous pressures

applied. This type of press gives a pressure which can be compared to a squeeze, in contradistinction to other presses which do their job mostly by impact. The steady pressure exerted by the knuckle-joint press enables the metal to flow equally under the punch, and fine intricate embossing is thus made possible, whereas a blow would not give the material an opportunity of entering the delicate engraving on the tool employed.

Indenting Dies.—This type of die is used mostly for forming "pips" or protrusions where needed, such as contact blades on a rotary service joint. They are usually quite simple in construction and manufacture, but dependent on the sharpness of the embossed protrusion, so the tool is laid out with this end in view. Often it is very difficult to produce a "pip" high enough to do the job for which it is required without cracks occurring, the material employed being the prominent factor. This, in the majority of cases, is phosphor bronze, which must not be annealed. Should the material be brass or mild steel, the matter is simplified. Only by experimenting can a good definite result be obtained, and it is usually best to form the "pip" uppermost by a series of hollow punches (Fig. 168). After it has been discovered how much metal is drawn in by forming the protrusion, then this amount can be added to the width of the material, and the surplus remaining on the other part of strip finally cleared away.

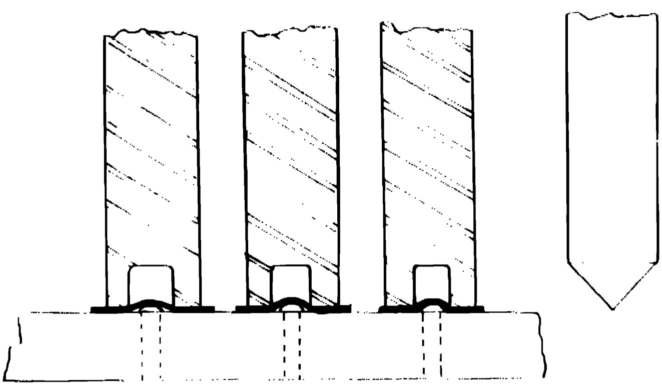


Fig. 168.—Indenting tool forming "pip."

Indenting Tools.—It often occurs that small holes are required in components or sheet metal that are far beyond the margin of piercing possibilities and hence they must be drilled. Many firms employ professional "markers off" who are usually quite rapid and trustworthy, especially where repetition work is concerned, but other firms prefer to indent or "spot" the centres of the holes in the various productions that are too thick or hard to be pierced by means of a press. It is quite a sound idea and brings the holes to within tolerable limits. The tool consists of punches ground to a point at about 60°, and mounted in a punch-holder to precision limits. A bolster is also made with a nest and other forms of location, on which the component to be indented can sit easily and flat. The tool, which is mostly used in a fly press, is adjusted so that the pointed punches enter the material from five to twenty thousandths, forming indentations which are then followed up with the requisite size drill.

Necking Tools.—The use of spinning tools is steadily declining, although there are many manufacturers who refuse entirely to dispense with this method of fabrication. It is now only adopted by modern manufacturers for very large jobs which cannot be placed under standard presses, although in some remote cases it is used in conjunction with a press, by constructing a tool to draw sufficient metal, probably in steps or corrugations, and this is afterwards spun to the finished shape on a wooden former, revolved by a machine similar to a lathe. Some very large light reflectors, mostly for export, are manufactured in this manner, but actually the amount of spinning done at present is very little. A few years ago if an article had to be " necked " it would invariably have been done by spinning, but using the modern methods it would undoubtedly be completed with a press tool in a considerably shorter time.

Necking is often found in the construction of electrical fittings that have to be retained in porcelain. A neck is formed in the cast product which fits round and locks both together. If this necking, which has to be continuous, is formed by the spinning method, the part is first " drawn up," in a sequence of operations, to the developed size, *i.e.* a certain quantity of the material is left for the necking operation, which will have the effect of shortening the component. The piece-part is now rotated at high speed on a mandrel, which is made from hardened tool steel to the required shape, and a former, carried on ball bearings, is forced up against it until the depth needed is produced (Fig. 169). Contrary to the design of some small spinning tools with knurled driving rings, the component requires nothing to drive it, only the pressure of the metal to metal. Stops are fitted to the machines operating these tools, to avoid further pressure after the necessary form is produced, and useless thinning of the metal is thus avoided.

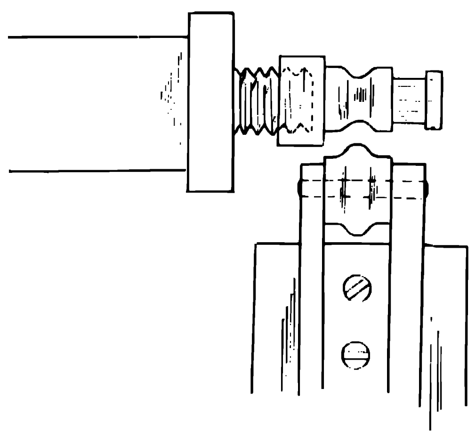


Fig. 169.—An example of spinning tool for necking.

Necking by Forming.—In modern production, the article referred to above would be " necked " after forming in a press tool, and it will be gathered from Fig. 170 how this tool is constructed. The central boss or forming die is usually made from medium-quality cast steel, afterwards hardened, and is constructed in two sections to enable the component to be removed after forming. The punch, which is also made in two halves, fitting inside the die, with the necessary clearance for the metal, is also made of hardened cast steel. The top portion, which can be called the " driver," and the bottom bolster are constructed from mild

steel. The spring plunger which will be noticed protruding from the driver is to hold the top portion of the die down as a resistance against the effort of the punch to force the two apart. The pressure required is considerable, and has to be adjusted to suit the component. After the press is operated and the neck formed, the component is pulled off with the upper portion of the die inside, and this is afterwards removed through the top and replaced on the tool. Two soft rubber inserts will be observed, the purpose of which is to force the two halves of the punch apart, although springs could of course be used. A slow-moving press is the most suitable for this class of tool, as pressure is more essential than impact.

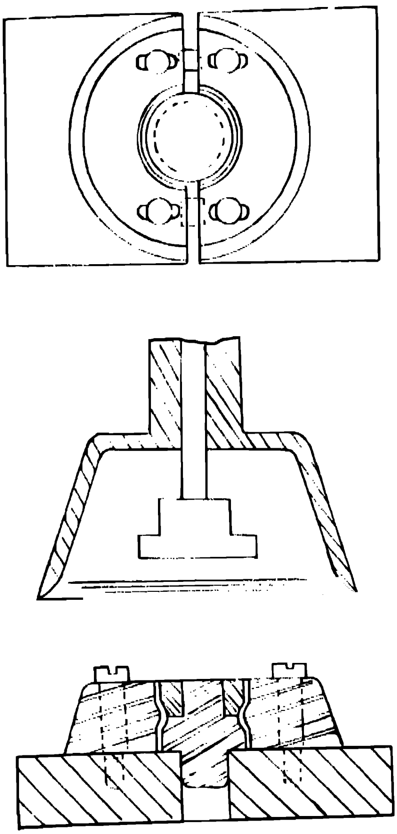


Fig. 170.—Press tool for necking, "splits" type.

Dies for Tapering.—In the production of tapered or conical shapes, it is sometimes necessary to employ quite different tactics to those which are used for the fabrication of shells of cylindrical form. The depth of the component in conjunction with the diameter and also the taper required are of considerable importance according to the class of work being produced. It is quite possible, in many instances, to form a shallow tapering piece-part from a flat blank in a single operation; on the other hand, many apparently simple tapering forms can only be produced by a sequence of operations. The form given to any component in a primary operation is always governed by the final shape that the object will eventually become. Conical shapes formed directly from a flat blank are very apt to crinkle or fracture before the part can reach the final shape required. Experience is very helpful in determining where and how much surplus material is beneficial in forming the shape desired, without unnecessarily increasing the resistance. Nothing is really so valuable as a comprehensive study of methods which have already proved successful. In many instances, with the forming of conical or tapering shells with open ends, it is necessary to leave one temporarily closed as a resistance against the final drawing process, also to avoid splitting at the smallest diameter which might possibly occur. With a conical-shaped punch and die, when the necessary pressure is exerted by the press, the action which takes place is to spew the metal out, or force it down to the largest diameter. After this component has been formed,

the bottom is " knocked out " with a piercing tool made for the purpose. The final operation can be accomplished in the lathe with a box cutter, dependent at what angle the bottom edge of the metal requires to be. A cup is drawn in two operations by similar tools to those shown in previous sketches, and the final forming is completed in the tool shown in Fig. 171.

Tapering metal under a press is a very difficult process, requiring special heavy-duty machines to cope with it. It is a procedure that is not often adopted, and its applications are strictly limited. When a shell is drawn up and it is required that the metal forming the walls shall be tapered, it is invariably done in a capstan lathe. To purchase material already tapered by extrusion and rolling offers so many advantages that it would be extremely uneconomical to attempt to taper metal by direct vertical pressure. The copper segments which are a component part of the commutator of an electric motor are " blanked out " from the strip metal, which has been previously tapered by extrusion. The firms that produce these articles require such enormous quantities, and in addition the friction set up by the copper on the tool makes it necessary for the die to be composed of special-quality high-speed steel. One firm has these special dies made from " Widia " steel[1] at a heavy cost, but presumably this is economical in the long run.

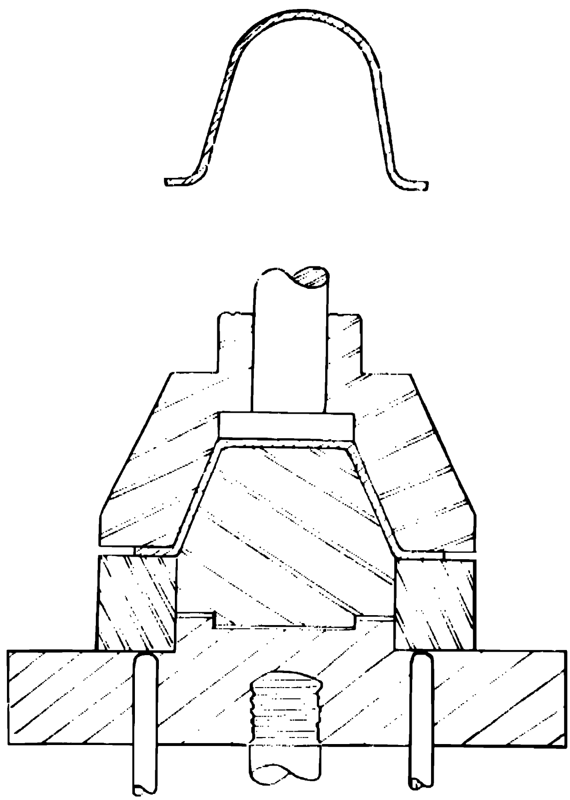


Fig. 171.—Cone-forming tool—final draw.

Swaging and heading dies are in constant use throughout the engineering production world. Swaging very small articles, such as flattening a piece of round or square wire and then cropping it to a desired shape, is a process performed in very simple tools and needs little explanation.

[1] " Widia " steel, which has a hardness only slightly below that of a diamond, was originally manufactured by Fried Krupp at Essen, Germany, but a plant has now been laid down at Coventry, and the material produced there, although of the same quality, is called by the trade name " Wimet."

Heading Dies.—These have, in the past, caused considerable trouble, owing to the difficulty in producing a steel to stand up to the heavy strain, but this has been successfully overcome and steel manufacturers are now able to offer special material for these tools. A heading die is a very simple affair, consisting of a hole in a piece of steel which forms the die, and a flat punch which descends and flattens the end of the material from which the bolt or pin is being made, this being usually round mild-steel rod projecting from the die face, an equivalent amount to form the bolt head. The pressure needed to cause the metal to flow under the punch is obviously considerable, but this stress has now been greatly reduced by having a small hole drilled in the end of the rod which is to form the head. This hole is usually drilled in the capstan machine to a predetermined depth by development (Fig. 172).

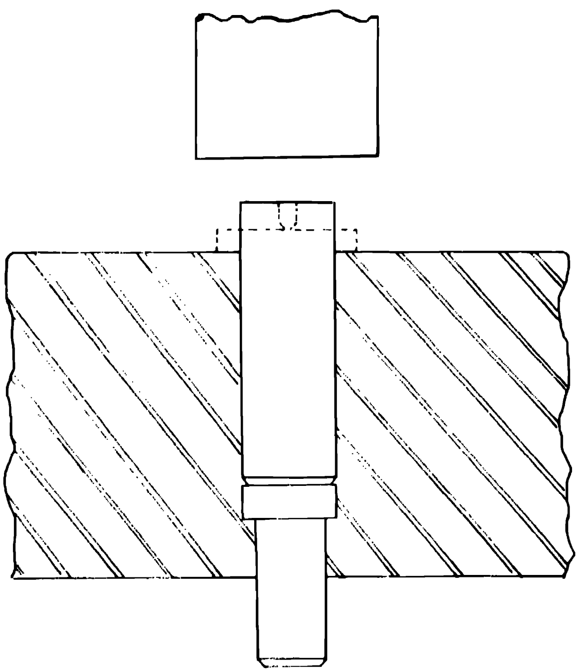


Fig. 172.—Heading die with component in position.

Lettering and Stamping.—This is a job that is easily completed with the valuable aid of a fly or hand press in those establishments where quantities of a given fabrication have to be stamped with a number and "country of origin." Sometimes the lettering stamp is made in one piece by an engraver, in other cases a group of single stamps are used, held in a mild-steel stock, specially made for the purpose. The anvil or bed upon which the component is laid for stamping must conform to the contour of that part which is to receive the lettering, otherwise distortion will occur. Delicacy in setting the press is essential in order to obtain just the depth needed, as if the letters or figures are allowed to enter the metal too deeply, it will cause spreading. Often when a component requires to be stamped deeply, this is done before the final forming operation, so that any distortion is then rectified. In very large factories, where high-speed production is employed, elaborate special machines are used for this class of work, often hopper or band fed.

Tools for Wire Forming.—The majority of wire-forming tools are made on the cam principle. They are usually more simple to design than ordinary bending tools, especially if they are to form spring wire, as the

wire can often be forced over a punch which forms a loop, and then is merely "stripped off," with the knowledge that the springiness of the material will help it to resume the original shape produced. Fig. 173 is a sketch of a simple tool to form a wire spring with a loop. The pieces of spring wire are first cut off to length and laid in a groove by the operator, who handles them with a pair of long-nosed pliers. When the tool descends, the pressure pad, which is fitted with very light springs, comes to rest on the two forming punches in which the groove is machined. Continuing the descent, the forming punch forces the wire down, and at this moment the cams come into action, moving inwards towards the neck of the punch, thus forming the loop. Owing to the fact that the end of the punch is made spherical, the wire loop usually slips off sideways at the upward movement of the tool, but should it not do so, it is just pulled off by the operator.

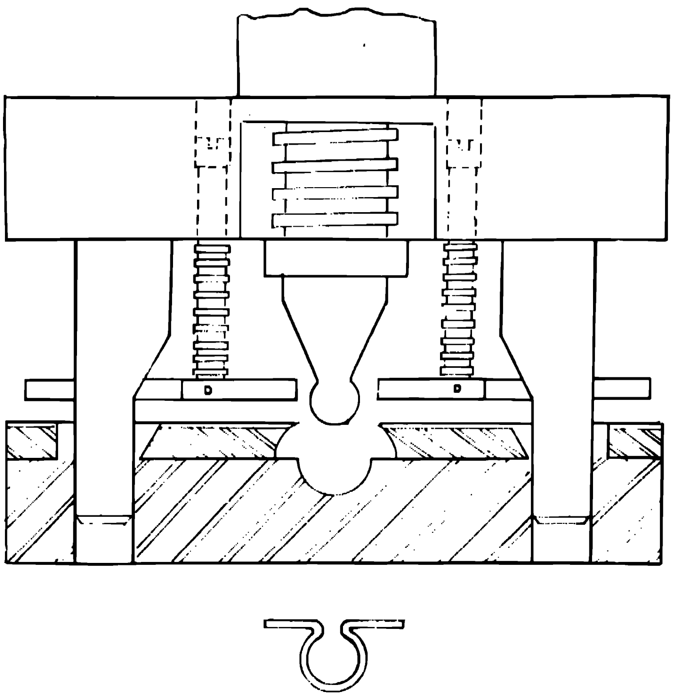


Fig. 173.—Forming tool for wire spring.

As a further example of wire forming, a simple tool to form a "U" or staple may be considered. The pressure pad, which in a case of this description is best made from mild steel carburised and case-hardened, has a recessed slot machined in it to receive the wire between two small pin stops pressed in. The punch and die, made from cast steel, are hardened and tempered. In operation, the punch descends on to the pressure pad, lightly trapping the wire confined in the groove, and, continuing the movement, forms it over the punch; the pressure pad, moving down supported by the springs, maintains the wire from twisting. It only requires a little thought combined with a knowledge of metal forming to design a dependable form of simple press tool.

Trimming Tool.—There are possibly more varied designs of trimming tool than of any other form of press tool. Nothing in this line is really standardised, as for each trimming job there are so many different ways in which it could be accomplished with probably the same result. The

only thing to be considered is the type of tool which will do the job in the most economical manner. One method by which a rectangular box is trimmed has already been dealt with (Chapter 6, Fig. 130), *i.e.* a trimming tool made on the blanking-tool principle. This method should always be used whenever possible, as the tool is simple and durable. It is, however, only applicable when a box has been drawn by the double-action method and the rim, which was held by the pressure pad, is retained at right angles. This is not always the case, and a rectangular box may have passed right through a die in its final stage, which makes it necessary to alter the design for trimming the top rough edge.

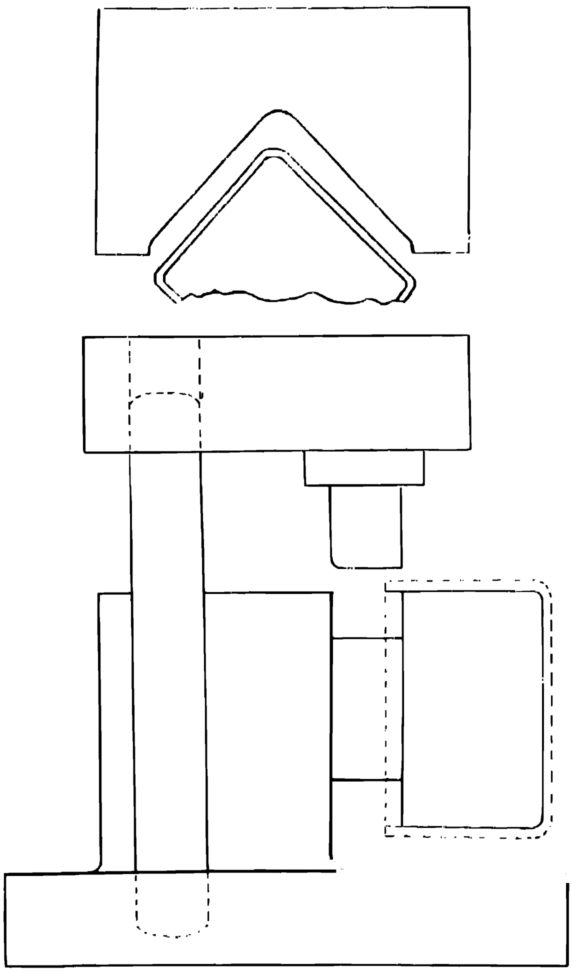


Fig. 174. Box-trimming tool component in position.

The tool shown in Fig. 174 is admirably suited for a trim of this description. It is completed in two operations by turning the box round to 90°. The first operation trims off considerably more than the second, but this, it will be observed, is to retain balance. The tool is constructed on the pillar principle, which is essential to absorb and counteract the side stress, which in all cropping operations is considerable. Trimming tools of this type are capable of prolonged action and extended life, and if sufficient steel is left on for re-grinding, this can be done over and over again. The upper cutting steel is ground on the vertical face and the lower tool is ground on the horizontal plane. The type of tool already outlined can also be used for trimming cylindrical fabrications, but it is usual to anneal the top edge before doing so, as this often becomes hard and fragile by the previous drawing operations.

Trimming for Location.—When stock can be procured of the required width for blanking one or two rows of parts in a " follow tool," this type

of tool is often fitted with two or more piercing punches owing to the difficulty in maintaining precision location. Pilots are then fitted on to the punches in other parts of the tool to " pick up " any error which may occur in the feeding of the material, an accumulation of which, if allowed to run on without balancing, would soon cause double-blanking, and many scrap piece-parts. Another method which is employed to effect balance is by having the stock strip oversize and the tool fitted with trimming punches. These punches are usually placed one on either side, and enter the material in advance of the remaining punches, thus maintaining it in

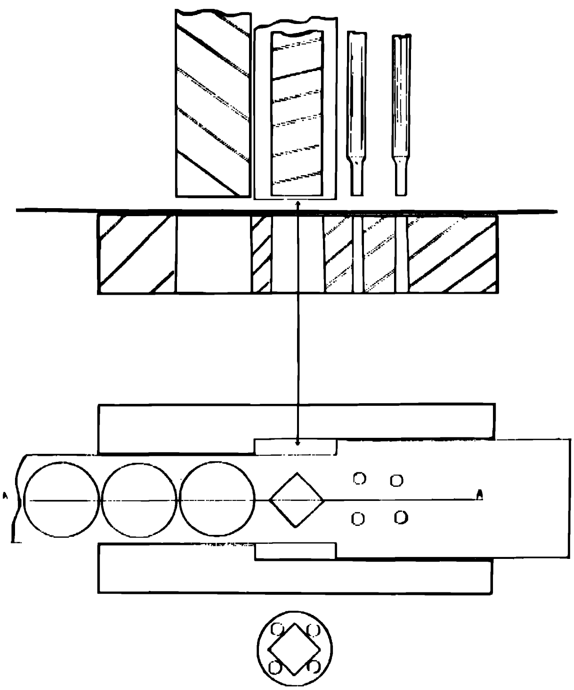


Fig. 175. Press tool fitted with trimming punches as a means of locating strip.

a rigid state when the other part of the tool strikes. It also serves another purpose, *i.e.* the trimming is done in steps along the edge of the material, and this acts as a stop, since each movement comes into contact with a protrusion on the die face which is provided for that purpose (Fig. 175).

Another variation of this principle is to have small piercing punches fitted to the tool which make small holes all the way along the strip of material being worked, as in a cinematograph film ; pilot pins are also fitted which enter into these holes at a successive stage, rectifying any error occurring in the sequence of operations. It will be realised that some means of balancing location must be incorporated in all tools of a progressive class, as any error, however small, is accumulative.

With an ordinary piercing and blanking tool with the pilot fitted to the blanking punch to " pick up " in one or more holes needed in the component being made, it is so arranged that the pilot or pilots on entering pull the material back away from the stop approximately five to ten thousandths, as, if the reverse happened, jamming and distortion would occur.

CHAPTER 8

DIE-MAKING

WITHIN the last twenty years, the use of dies for the production of articles from sheet metal has expanded enormously. Vast quantities of parts have to be produced with great rapidity by these dies, extreme precision being essential.

There is practically no limit to the scope of modern tool-rooms in their capacity for constructing press tools capable of performing the many and varied operations necessary to produce reliable and interchangeable parts in the press. The motor-car engine and body, the wireless set, the telephone, and indeed all branches of engineering production, are to-day largely dependent upon parts produced by the press tool.

The size and shape of the punch and die are usually determined by the form of the product, but where it is at all possible these should be so proportioned that there is a minimum resistance to the flow of material being used.

It is usually a case of the application of the principle of " trial and error " to obtain the most satisfactory shape of punch and die for the production of the article required. Theoretical size in development can never be strictly adhered to because of the thickness or gauge of the material and its hardness, while slight variations in the allowances made in the designing of the press tool will also affect the final result. By a system of compiling data from all previous jobs, some tool-designing offices do, however, get very near to determining definitely the necessary size of blanks before these are finally developed in the tool-room. Where there is good collaboration between the die-room and the drawing-office the problems of design are made much easier. The theoretically developed size, calculated to three places of decimals, is entered on the tool drawing, but always a query mark is added. The tool-maker is then expected to make up trial pieces and bend them or form them to the required shape, making notes as he progresses, and when finally he arrives at the definite dimensions, he makes an alteration to the theoretical figure on the print of the tool drawing. When tools are completed, the information is passed to the records department, the tool-room print being compared and adjusted to the original drawing. Thus is obtained the practical data to which the job is worked.

The improvement in the quality of good-class tool steel has done much to minimise the difficulty experienced in the manufacture of intricate shapes, but it does not necessarily follow that all press tools are made

from hardened steel; indeed, this is far from being the case. Many firms, for the manufacture of brass pressings, and also pressings in mild steel, make a soft die and a hardened punch, while in the case of boxes and similar articles requiring the working of very thin tinplate, the die is made hard and the punch remains soft.

It is a very difficult matter to make press tools for the blanking of very thin metal, as immediately the tool becomes worn it will throw up a burr on the material which is being worked. To overcome this difficulty, the usual method adopted is for the soft part of the tool to be " bumped " or " hammered " up, the other portion being re-fitted by shearing. After the shearing process in the tool-room, the punch is not removed again from the die but is passed to the production department, where it is set up in a press and operated, thereby avoiding the possibility of the punch taking up another position relatively to the die upon being reset—which it would invariably do.

Like most other branches of engineering, tool-making has improved from year to year, the war of 1914–1918 giving a great impetus to this particular branch of the industry. The blacksmith was the first tool- and die-maker, as, when he had a repetition job or an article to make of which any quantity was required, he made " top and bottom " tools. These were mostly crude-shaped dies which had been drilled and chiselled out to some semblance of the form required. Metal was then heated in the forge and placed between these dies, which were then struck with the sledge hammer.

Other branches of tool- and die-making undoubtedly evolved on much the same lines, until we come to the tool-maker of about thirty or forty years ago. The mechanics employed in those days were undoubtedly experts, as they lacked all the expensive luxuries in the way of precision machinery which is available to-day, and they had to do their very tricky job usually with the aid of a vice, drilling machine, and a few hand tools.

There were at the time very few presses of any description, and small blanks, etc., had to be produced by the same method as that employed by the blacksmith, *viz.* the hammer. Small blanking and piercing tools were made, composed of a die, a punch, and usually two guide strips to locate the material, and also to position the punch. Strips of thin metal were placed between the punch and the die, and a blow given with the hammer, sufficient force being exerted to drive the punch through the material, after which the metal was stripped off and the operation repeated. The men responsible for making these tools were usually very proud of them, and one of the best blanks from the number that was first struck would be fastened on to a card and kept as a sample. It was the usual practice for the mechanic to exhibit these samples as proof of his handicraft when he went after a fresh job.

Up to a very short time ago, the tool-maker's art was represented by a dexterous use of the file, but this has now been superseded and im-

proved upon by one of the most useful of modern tool-room appliances, the filing machine (Figs. 176 and 177).

Filing Machines.—The first of these machines was welcomed as a great boon to the tool-maker, and owing to the ever-increasing demand was quickly followed by better and improved models. The original filing machines did the dual job of filing and sawing out by the use of a vertical reciprocating motion, but the backward movement of the saw was a great disadvantage, and a much-improved type of machine was produced in which the reciprocating saw was replaced by a band saw, and to-day a tool-room is hardly complete without both of these valuable machines (Fig. 178).

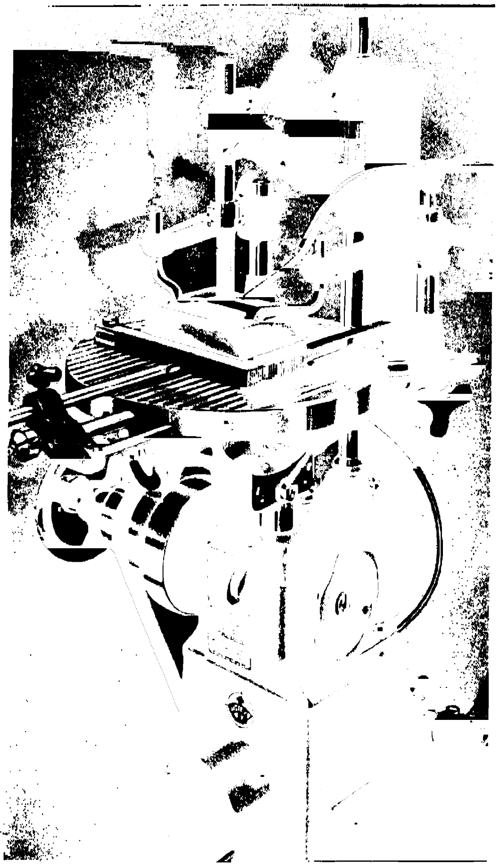


Fig. 176.—Thiel die-filing machine. (By permission, E. H. Jones (Machine Tools), Ltd., London.)

Fig. 177. —The filing machine in operation.

The production of the enormous quantity of dies which are in use in the factory at the present time was considerably helped along by the steel manufacturers, who were able to produce suitable steel to withstand the heat treatment to which dies have to be subjected in order to harden them sufficiently to resist the incessant hammering to which they are subjected when used in mass production.

Until quite recently, the making of a blanking die possessing a more

or less awkward form was a matter of chance, as there was usually a considerable amount of distortion during the heat-treatment process; but now this anxiety has become almost a thing of the past owing to the production of high-grade carbon steel which will not "shift"—to use the trade term—when it is subjected to the required heat for hardening purposes. This steel is now manufactured and sold in great quantities.

Preparation of Blanks.—The design and construction of dies for blanking tools is governed in the first instance by the area of the blank. A large tool is constructed of a top and bottom bolster, cast iron being used for thin stock, as, for instance, in motor-car body production, while cast steel is used for heavier material. These two bolsters are connected together by four stout steel pillars which are a tight drive-in fit in the lower bolster and a slide fit in the upper bolster, the pillars thus acting as guides. In many instances the upper bolster is fitted with steel or bronze bushes, thereby reducing the friction as it slides up and down the pillars, and at the same time facilitating renewal after wear has occurred. But many large die-rooms just bore through the cast iron, this being found quite suitable, especially if the design of the article being produced is continually being changed, necessitating new tools.

Fig. 178. Thiel band-sawing machine set up for cutting at an angle. (By permission, E. H. Jones (Machine Tools), Ltd., London.)

The method of manufacture adopted by the makers of the large blanking dies used in the motor-car body and aircraft works throughout the country may now be outlined. The bolsters are usually cast and then roughly machined, after which they are seasoned for two or three months to avoid any distortion which may occur as a result of stresses set up by cooling. They are then re-machined by the planer, a finishing cut being given on both sides of each.

A template, which has been previously developed and tried out, is supplied to the die-maker by the template department, a drawing being also supplied, this being a print taken from a standard sheet with the profile of the template sketched in. In the usual order of procedure, the steels are now prepared for both the punch and the die. In the construction of large dies it is not usual to employ very large pieces of steel, the die being built of small sections, the reason for this being that

large pieces of steel are more apt to distort and warp than small pieces, while heavy material is obviously much more awkward to machine and handle in the heat-treatment process ; moreover, if the edge of a large die breaks away when in use, then a small section can be easily replaced at little cost as compared with the cost of replacing the whole die.

In a straightforward blanking tool, second-quality carbon steel is used for the punch and also the die, but should any abrupt protrusions occur, then that section only is composed of the very best-quality tool steel. The blocks of steel generally used for this class of tool are usually about 6 inches long, 4 inches wide, and 4 inches deep, although they can be obtained in smaller sizes to suit any particular job. Larger sizes are, however, seldom employed. The sides, as well as the top and bottom, are now squared up in the shaping machine, and finally they are surface ground on a large rotary grinding machine. In this kind of work, the punch is always the first part of the job attacked by the experienced man. The set of blocks which are to form the punch are now drilled to accommodate Allen screws, and holes are also drilled and reamered to accept two good stout dowels to each block (Fig. 179).

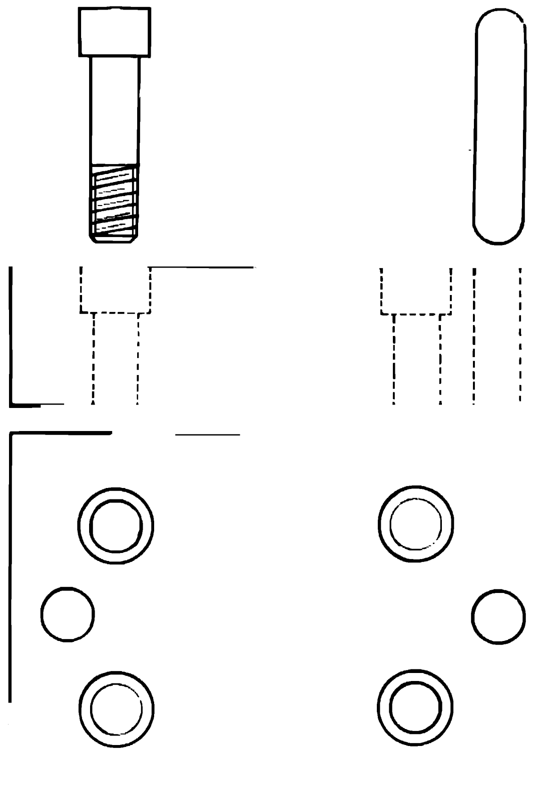


Fig. 179.—Prepared die blank.

The blocks of steel are now butted together and laid on the upper bolster face in a form which will include the whole of the template profile ; a scriber is then run round the inside of the bolt holes only, thus marking their position on the bolster. The holes on the bolster are then centre-popped, drilled, and tapped out to the size of the screws being used. The dowel holes are not transferred until the final assembly and after hardening.

The blocks are now placed in their positions on the face of the bolster and screwed down tightly, after making certain that they are butted snugly together. Some form of colouring material, such as copper

sulphate, or better still, blue lacquer, is then usually rubbed over the surface of the steels, and when this is quite dry, the template is laid on the face and held down very tightly, a thin hardened scriber being run round the edge of the template, thus marking the steels the shape to which they have to be machined (Fig. 180).

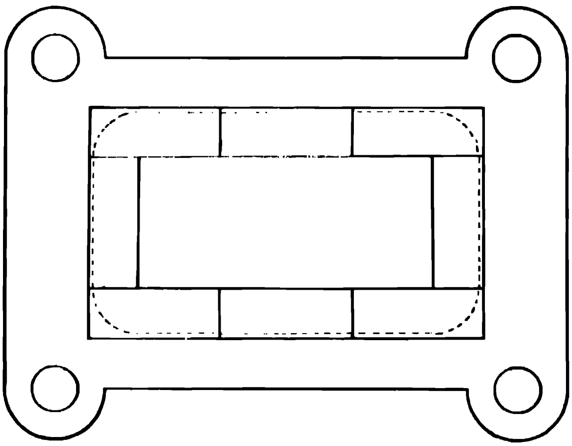


Fig. 180.—Method of marking out the punch profile.

In large die-making shops, especially where American methods are used, the modern shaping machine is employed to great advantage, as milling is much slower, and, for that reason, it is also a much more costly operation. The punch steels are now removed from the bolster and machined right down to the scribed line in the shaping machine. A great many shaping-machine operators in this class of shop are very clever, and they prefer to fix the steels in the machine vice with the working lines at the back, so that when the tool finishes the cut, the edge that breaks away is at the bottom and not at the face. If the reverse occurred, of course, the face would need grinding away in order to obtain a square edge. The filing machine now comes into operation, the machining marks being rubbed away, and the steels generally cleaned and squared up ready for the hardening process.

Heat Treatment.—Much has been written regarding the theoretical side of heat-treatment processes as well as of the practical difficulties involved in giving the correct heat treatment to steel, but the practical method which is employed in the majority of the large die-making shops is quite simple and effective for this type of work.

The steels are placed in a muffle furnace and brought to the required temperature, this being usually given by the steel-makers. They are then withdrawn and quenched in clear running water to a " black heat," *i.e.* when the sizzling stops, after which they are laid in oil to cool off. This method of hardening steel has the effect of giving a hard outer surface for cutting, and a soft core to withstand the vibration. The hardened steels are then tested in the hardness-testing machine, after which they are surface ground and the edges just cleaned up with a stone. The steels are now put back on to the bolster face and screwed down tightly into position, after which the dowel holes are transferred right through the bolster by drilling and reamering, and the dowels driven into position. It is important to note that the dowels must not be too tight or the steels may crack.

The same method is now employed with the lower bolster and die steels; but as they are to form the female part of the tool or the die opening, the die steels will slightly overlap on the inside profile of the template, the excess material being eventually machined away (Fig. 181).

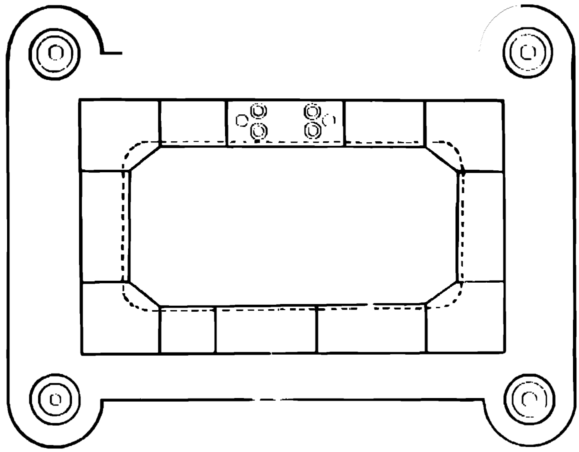


Fig. 181.—Method of marking out the die opening.

Many of the large blanking tools are too heavy to be lifted about by hand, and in good modern die-rooms considerable use is made of the overhead crane. The bolster containing the punch is now lowered either by hand or by crane down on to the four pillars, which have been previously fitted, until the hardened punch steels rest on to the soft die steels, when the thin scriber is run round the edge, thus marking the die opening. Now commences the die-shaping operation, and the steels are shaped back until the scribed line is reached.

It now becomes a job for the expert fitter or tool-maker to bed the die steels on to the punch, a tolerance of only ·001 inch being permitted, this being determined with the aid of a feeler blade. This process is usually performed by having the punch bolster replaced on the pillars, and the die steels, after having been smeared with a little paste composed of red lead and oil, are pushed up against it.

The diligent use of the filing machine, the hand file, and the precision square—combined with patience—will eventually accomplish this difficult job, and a perfect fit is obtained between the punch and the die, after which the die steels are ready for hardening in the same manner as were the punch steels before them. After hardening, the die blocks are ground and cleaned up, returned to the bolster, and bolted down. They are then pushed up tight against the punch and feelers inserted all round to check the gap, any necessary adjustment being made by having, perhaps, two or three thousandths ground off one or other of the butt faces until they are a good snug fit. The top tool is then again pulled off, the holes in the die steels are transferred through into the bolster, and the dowels driven into position.

Theoretical die clearances serve a very useful purpose, but not nearly so much notice is taken of them by the practical tool-makers as one would be inclined to believe. For any metal up to and including $\frac{1}{32}$ inch thick, the punch is made a nice slide fit in the die; over and above this amount a good workable allowance is $\frac{1}{1000}$ inch clearance for metal

·034 inch in thickness, the clearance then increasing by ·001 inch for every increase of ·030 inch in the gauge of the stock.

The Parallel Die.—It will be noticed that in the foregoing explanation of the production of a large blanking tool, no mention has been made of die draught or "backing off." It should be noted, however, that with this type of tool, draught is quite unnecessary, as the piece part is ejected by the use of a spring stripper and does not pass right through the die. Where the area of the blank is considerable and the stock being cut up is on the thin side, this type of tool is always employed, as the stripper ejector acts as a pressure pad, being so constructed that when it is extended to its fullest amount by spring pressure, it is just proud of the die face (Fig. 182). Hence, when the punch descends, the stock is trapped between the pressure pad or stripper before the cutting edge of the die comes into action, thereby minimising the possibility of the material being drawn in between the punch and die.

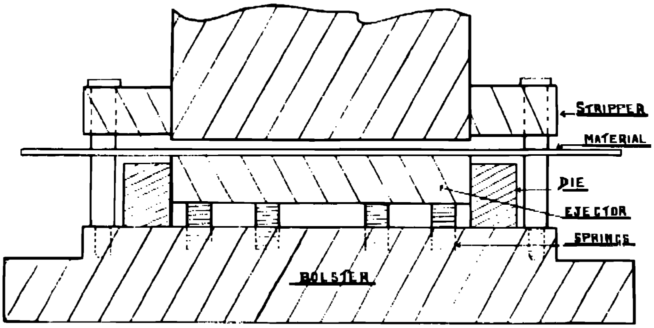


Fig. 182. Section of large blanking die as example of construction.

The production of strippers for these large tools was formerly a fairly difficult job, but it has been considerably simplified in recent years. A large piece of boiler plate about ¾ inch thick is requisitioned and marked out from the template that was used for the punch and die. The line is then followed round with the oxy-acetylene cutting flame, the inside part, after cleaning up and surface grinding, becoming the pressure-pad ejector, the outer part becoming the stripper plate, which strips the waste sheet which remains on the punch after it has passed through in cutting the blank.

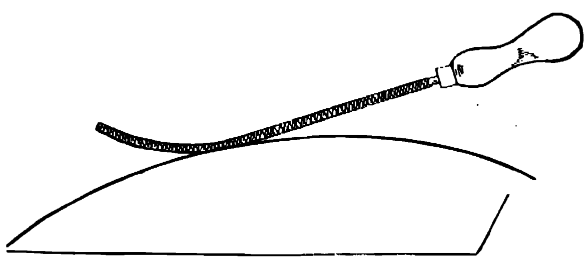


Fig. 183.—Bent files for certain jobs.

There are many instances in die-making where it is impossible to use the filing machine, as, for example, in the case of a large drawing punch with many radii and contours. These are usually attacked in a normal shop with the hand and pneumatic chisel, afterwards being finished off to a smooth polished surface with the hand file. It is a difficult matter to file a convex surface with a flat file, but one that has been slightly bent

after heating to a dull red, and then re-hardened, will in many cases be found of great value (Fig. 183).

In many large modern die-rooms, for the production of dies and punches, much use is made of the Keller automatic profiling machine. The accuracy of the work produced on this machine is of such a high standard that the need for hand finishing is entirely eliminated. Moreover, several operations may frequently be performed with one set-up, as, for example, a die impression can be cut and the bolt and dowel holes bored accurately in position relatively to the profile. The main feature of this machine is its ability to follow practically any shape or form with the automatic tracer control, this being so sensitive that the shape produced by the cutter is a faithful reproduction of the model or template. This tracer is mounted above the cutter, and is adjusted by micrometer screws. During the operation, the tracer and cutter move in unison, the tracer following the shape of the master form, and the cutter duplicating that shape in the work, this being accomplished by the extremely delicate electrical control of the tracer. There are two distinct operations performed by the tracer control. The first makes use of a profile tracer which guides only the vertical and horizontal movements of the machine, the cutter having already been set before the operation is started, a template being usually employed in this operation (Fig. 184). The tracer point is in continuous contact with the edge of the template as it passes round it, thus guiding the path of the cutter to reproduce its shape accurately on the work. The cutter can be as easily located for a heavy roughing cut as for very fine precision work. The second operation performed by tracer control is in the reproduction of reliefs in three dimensions. Once the machine is set it is fully automatic in operation. The machine controls are set to cause the tracer to cover the entire surface of the master in a series of parallel strokes, either vertical or horizontal, the length of the stroke being adjustable; and at the end of each stroke the machine feeds before commencing the next. The third dimension is controlled by the automatic tracer,

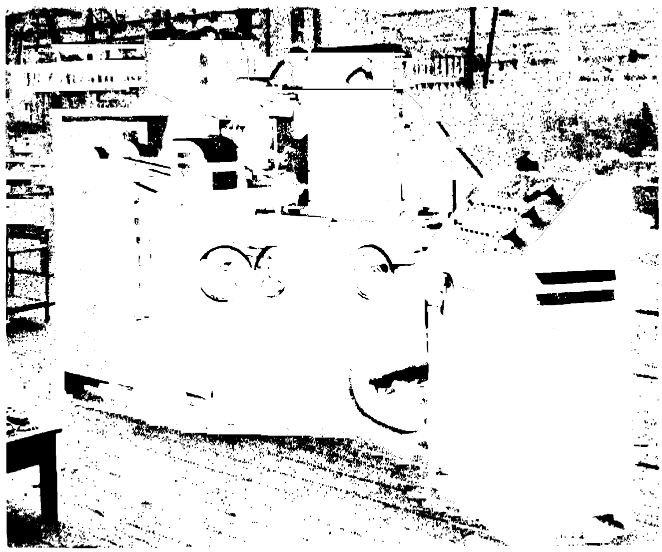


Fig. 184. The Keller automatic tool-room machine. (By permission, Alfred Herbert, Ltd., Coventry.)

Directly contact with the model is made, varying degrees of pressure at the tracer point (created by the contours of the subject over which it is passing) cause the machine to travel in unison, consequently faithfully reproducing a complete form of the model. This operation is employed for forming-dies.

The Keller automatic profiling machine is shown at work producing a medium-sized blanking tool. In Fig. 185, the template is seen above and the die blank below, the die steels in this instance being screwed on to the bolster before being mounted on to the machine.

Fig. 185.—The Keller. Machining a blanking die.

A template is made of the die and also the punch, with the necessary amount of die clearance, and the accurately machined edges will be noticed in the illustration. After machining, the whole of the die steels—the various parts of which can be also seen in Fig. 185—are taken apart after having been carefully marked, and they are then hardened and tempered. The steels are then surface ground on both sides to ensure them being perfectly flat, otherwise when the bolts were drawn down they would be liable to crack.

When the top and bottom bolsters are completely assembled with the punch and die steels in position, the punch is entered into the die with very thin packing strips all round, in order to equalise the die clearance in every direction. The complete assembly is then fastened together with clamps, and the holes to accept the pillars are bored right through both top and bottom bolsters; thus assuring perfect alignment.

Precision Holes.—Nothing in engineering practice, especially tool-room work, is of greater importance than the exact alignment of holes. Where great quantities of certain articles have to be produced; in order to facilitate assembly and interchangeability, the importance of obtaining absolute precision in the size and position of the various holes cannot be over-estimated. For years the tool-maker of the past struggled with the problem, scheming and inventing gadgets in his endeavour to over-

come the elements making for lack of precision. Spurred on by necessity, many and varied are the inventions that have been placed upon the market during the last few years, some costing a few pounds, others costing many hundreds, all of them having as their object the production of holes with absolute precision. Holes can be classified in four groups. In number one are those for which anything will do; no advice will be needed in the drilling of them. In number two are the holes that require to be somewhere within ·005 inch. Number three includes those that require to be somewhere within ·002 inch, and the remainder those that must be "spot on" or within a tolerance error of ·0005 inch. With regard to the second class, these can usually be obtained by first drilling a pilot hole, if care is exercised. After the spot has been carefully marked off, and centre-popped, a small pilot hole is drilled about one-sixth the size of the final hole needed, it being inadvisable to use a drill of less than $\frac{3}{32}$ inch, as it is liable to bend, in which case the hole will run away from the perpendicular. When this pilot hole has been drilled, it should be checked with a mandrel inserted in the hole for position and alignment, any discrepancy being rectified with a small round file before being finally opened out to the required size (Fig. 186).

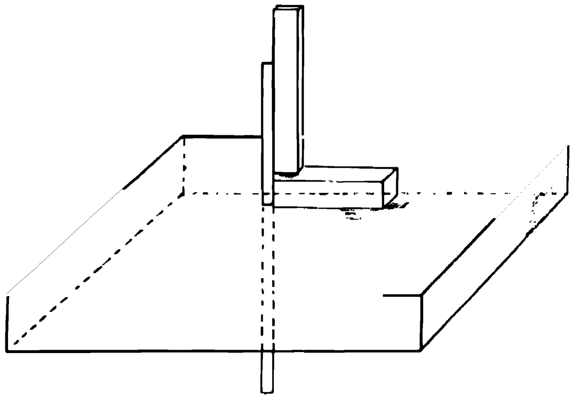


Fig. 186.—Checking a pilot hole with set-square.

Another method by which holes not requiring a great deal of accuracy can be drilled, particularly applicable to the case of a die, is as follows: Two sides of the die are made square to each other, and some means arranged to fasten the work down on the table of the drilling machine. The holes are then located with a precision depth gauge from the sides of the job, adding half the drill diameter to the reading. In Fig. 187 it will be noted that a centre

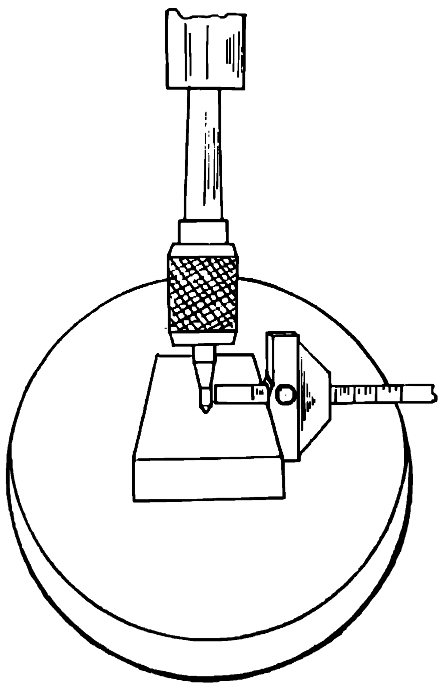


Fig. 187.—Method of "spotting" a hole with a depth gauge.

drill is being used ; this, of course, being equally effective for "spotting" the hole, which can afterwards be drilled and reamered to size.

For holes in the third class, which have to be accurate to within ·002 inch, different methods are required. Marking off will necessarily play a most important part in the procedure, and the Vernier height gauge can be used to great advantage (Fig. 188). In tool-room parlance, the positions for these holes will have to be "squared," which means that in addition to the two centre lines crossing at right angles at the exact position of the centre of the hole, four other lines are scribed defining the outer edge of the radius, that is, tangential to the circle, so that when the hole is started and finished it can always be examined for position, with the aid of a good magnifying glass. If the circumference is within the square, then the hole must be within fairly close limits.

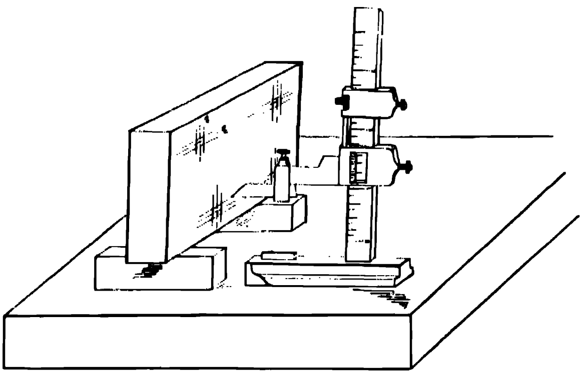


Fig. 188. Precision holes defined by squares.

An alternative method for boring holes requiring this degree of accuracy, and one which is often preferred, is in the lathe with the use of a "wriggler." Instruments of this type can be purchased, these being made with a knuckle joint, but if one is not available, then a length of silver steel can be used instead, one end being turned to a point which must be concentric to the remainder. After the hole position has been carefully marked off, a good clean centre-pop indent is made at the junction of the two centre lines. The part to be bored is then mounted on the face plate, and lightly clamped. The "wriggler" or the silver-steel rod is held in a small chuck in the tailstock, and the pointed end inserted in the centre-pop mark on the job. An indicator is mounted, usually on the tool box, with the contact finger resting on the wriggler, as close up to the work as possible, as shown in Fig. 189. If the machine is now pulled round, the indicator will register the amount that the hole-to-be is out of position, and adjustment can then be made until the indicator reads "steady," after which the hole is drilled in the usual manner.

There is also the ordinary turner's method of positioning holes with the use of "buttons"; and another and simpler procedure, somewhat similar to this and adopted by many old-time tool-makers, in which the drilling machine is solely used. This system is known as the "button and block" method, and is extremely useful, being much quicker than setting-up in a lathe. Buttons are made of a size suitable to the holes required, preferably somewhat smaller, having a small clearance hole through the centre, which must be a very slack fit on the screw being used. The

block of cast steel is then trued up and a hole bored, in which the buttons are a good slide fit. Both the steel block and the buttons should be hardened and tempered. The part to be bored is next roughly marked off, and small holes drilled and tapped to receive the button-

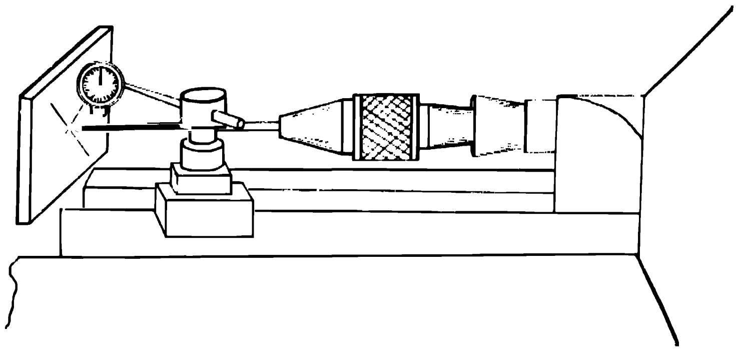


Fig. 189.—Setting up for boring by use of a "wriggler."

retaining screws, which will be in the region of $\frac{3}{16}$ inch or 2 B.A., according to the holes to be bored and he buttons being used. The buttons are now screwed on, and with the aid of a micrometer, or vernier slide gauge, they are located to the exact position and the retaining screw is then tightened (Fig. 190). The block is then slipped over one of the buttons and tightly clamped in position. When all is secure, the screw retaining the button is withdrawn, and the button pulled out of the block. The hole through the block is then transferred through the job by drilling and reamering.

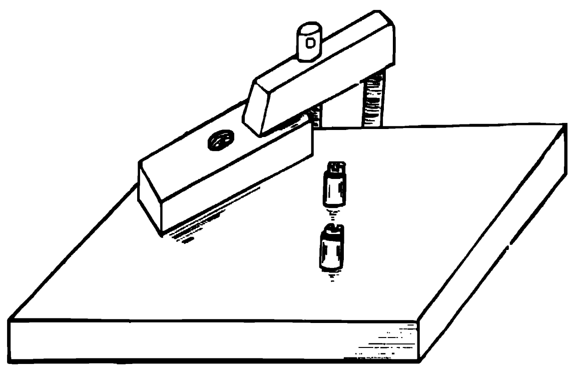


Fig. 190.—"Button and block" method of control when boring holes.

The Jigometer.—This was one of the first instruments marketed with a view to overcoming the worries of the tool-maker in drilling holes in the fourth class, *i.e.* those that require to be within very fine limits of error. The jigometer was invented by an old London tradesman, and satisfied at the time a considerable demand. It is quite an efficient instrument, and is in use in several tool-rooms to the present day. It consists of a "trued-up" cast-iron bedplate, with slots running at right angles, in which are retained bolts for holding down the job which has to be drilled. Directly above the plate there is a bracket with a fairly large hole in it to accommodate a series of "slip-in" hardened bushes. The position of the bracket is controlled by a finely threaded screw,

the movement of which in either direction is regulated by a vernier scale graduated to one-thousandth part of an inch. The part to be drilled is fastened on to the bedplate, which is in turn bolted on to the drilling machine. Starting from a datum or zero position, the first hole is drilled to the required size through a bush; the bracket is then moved to the next position, which is accurately located by the adjustment screws and the Vernier scale reading, and another hole drilled, the process being repeated until the job is completed.

The Jig Boring Machine.—There are very few up-to-date tool-rooms at present that are not equipped with a jig boring machine, of which there are several types manufactured by eminent engineering firms. The one illustrated (Fig. 191), the Genevoise machine, which is especially suitable for die work, is made in various sizes with many attachments for enabling awkward jobs to be carried out. It is simple to operate and rapid in action, being capable of boring holes of practically any size in any predetermined location consistently to within ·0001 inch, which for present-day mass-production methods is a very valuable feature.

Fig. 191. A jig boring machine by Société Genevoise. (By permission, H. E. Weatherley & Co., Ltd., London.)

The procedure in the modern tool-room is such that the lot of the tool-maker is far easier than it used to be. Where years ago the onus of responsibility rested on one individual, it is now in all large firms distributed between specialists in each particular department. The shaping section, the milling section, the boring section, the fitting section, the heat-treatment department, the grinding section, and finally the tool-inspection department—each is responsible for its own portion of the work. The fitter, who is really the key man, usually accepts more responsibility than the others, as he has to carry the job to the final stages. Sometimes he receives the material in the rough and hands it out to the various departments for machining, in other cases he receives the component parts of a tool already machined. The first thing to be done in the latter case is to check up the parts to the drawing sizes, this being very important, as each department will only accept responsibility for work done by themselves. In many very large works, such as the Ford Motor Co., this is unnecessary, as an inspection department is incorporated in each section—turning, shaping, milling, boring, grinding, etc. —and the tool-maker does not handle the part until it has been viewed by that particular inspection department. In most examples of press

tools, the die is the piece to concentrate on ; this certainly must be right, and in the case of small- or medium-sized tools it is finished to size, " backed off," hardened, and surface ground first of all. The punch, which has previously been machined roughly to size with about ·005 inch left on for fitting, is then very gently sheared right through the die. There is usually a tendency when shearing under a fly press to go too far ; this must most certainly be avoided, otherwise pieces will be pulled out of the punch, and, as a consequence, this component will have to be scrapped. It is sometimes the practice in certain tool-rooms to give the fitter a piece of steel on which to mark out the punch for machining. This can be accomplished either by setting it up on the surface plate, and marking it off with the vernier height gauge, or by clamping it on to the face of the finished die, and running a thin hardened scriber round the edge.

When the tool has been assembled, the most important problem is the " lining up." It will be realised that a punch entering a die with only one-thousandth of an inch clearance must be in perfect alignment and able to move perpendicularly to the die, otherwise it is useless. The assembled punch unit must be set up on an angle plate, and the indicator run along the punch, or at the very least, carefully checked with the small precision square. The punch is then entered into the die through the stripper plate, as in the action of working, and the top of the tool checked for faults in alignment.

Should any error be noticeable, the dowels holding the stripper plate to the die will have to be withdrawn and the tool adjusted to perfect alignment. The holes are then lapped out to their new position, and new dowels made and fitted to the required size.

Hardening and Tempering.—Quite a large proportion of tool-makers know little or nothing whatever about this branch of the business, the reason being that in the majority of large factories the hardening and tempering department is kept strictly apart, making it unnecessary for the ordinary mechanic to have anything to do with it. But undoubtedly every artisan connected with tool-making should acquire a practical knowledge of the heat treatment of steel so that, if required, he will be able to carry the job right through from the raw material to the final inspection of the finished tool.

One of the chief considerations in heat treatment is the quality of material used, but it may be stated that material of proved qualities purchased from reputable steel manufacturers can always be regarded as being thoroughly reliable. Moreover, the manufacturers supply their own formula for hardening, and if this is adhered to, very little can go wrong, especially if the operator is conversant with the practical technique of heat treatment, so as to avoid the snags or pitfalls, of which there are many. It is always advisable to use a pyrometer, that is, an instrument capable of reading high temperatures, as it is usually found that workmen hardening without using a pyrometer are more inclined to under-heat

than over-heat. This is due to the wish to avoid the greater of the two evils, but it must be emphasised that steel will not harden unless it is brought up to the required temperature.

For use without a pyrometer, the following table serves to indicate the relationship between the colour of the heated material and its temperature:

JUDGING TEMPERATURE BY COLOUR

Cherry red	740° to 770° C.
Full red	780° to 820° C.
Bright red	830° to 900° C.
Full bright red	910° to 960° C.
Orange	1,000° C.
Lemon	1,200° C.
White	1,250° to 1,300° C.

Steel producers say that it is wrong to suppose that high-speed steel cannot be overheated, and undoubtedly they are right, but it should be remembered that it is impossible to overheat with a gas blow-pipe, although it is quite possible with a smith's forge, and this is the only means available for obtaining high temperatures, unless special types of furnaces are employed.

Judging Tempering Temperatures by Colour.—After hardening according to the formula supplied by the firm, the article is cleaned up with a piece of emery cloth and placed on the hot-plate, which is usually arranged on a gas ring, or heated up by some other means until the required colour is obtained, when it is finally quenched.

In hardening cutting tools, common sense shows that the required temper must be at the cutting edge, the remainder of the tool being in all ordinary circumstances softer. For instance, when tempering a reamer, it should be hardened and then laid on the hot-plate, where it is rolled backward and forward to get an equal temper all the way up; but when hardening and tempering a chisel, where the temper would only be required at the cutting edge, the chisel is first hardened right out; the shank is then heated, watching the colour run down to the edge, and when the desired colour is obtained, the whole is finally quenched.

The tempering colours, starting from "light straw," which is round about 230° C., and finishing with "blue," which is somewhere round 300° C., are given in the following table. After the blue temper has been reached the material retains that colour until it is red-hot again.

TEMPERATURE AT TEMPERING COLOURS

Light straw	230° C.
Dark straw	240° C.
Orange	250° C.
Brown	270° C.
Blue-brown	285° C.
Blue	300° C.

TEMPERING TEMPERATURES FOR DIFFERENT TOOLS

Wood saws	300° C.
Screw-drivers	300° C.
Planing cutters	285° C.
Cold chisels	285° C.
Twist drills	270° C.
Punches and dies, taps and chasers, snaps	250° C.
Milling cutters, flat drills, reamers	240° C.
Scrapers, lathe tools for brass	230° C.

Silver steel should be heated to cherry red (740° to 770° C.) and quenched in water.

All articles, such as drills, reamers, etc., that have a tendency to distort should be quenched vertically and moved up and down.

For drilling very hard material with small flat drills, heat the drills to the same temperature, and quench in oil, using without tempering. With this method much depends on the heat, and care must be used to bring the steel to its lowest hardening point, otherwise drills will be soft. Very satisfactory and reliable results can be obtained by this method in cases where there is any fear of a tool breaking, such as small drifts, etc.

For very severe work, small tools can be quenched in glycerine, and then tempered to a very pale straw colour (230° C.). As an example of the use of this last method, mention may be made of the very small cutters used in the production of match splints, which, after much experiment, were finally made of silver steel, hardened in a mixture of glycerine and water—one part glycerine and one part water—and then tempering to " brown " (270° C.).

Temper of Steel.—Temper signifies the degree of hardness, which increases with the percentage of carbon contained in the steel, and which has no relation whatever to quality.

The suitability of steel for various purposes depends not only on the quality, but also on the temper or degree of hardness. Consequently, it is advisable when ordering steel to specify the purpose for which it is intended, so as to ensure the most suitable material for the job being supplied. The cost necessarily increases with the quality of steel, as in most things, but the best quality usually pays in the long run, especially where a tool of high endurance is needed, as less frequent re-dressing is required.

Judging Temperature by Colour.—" Cherry red " and " bright red " are rather elastic terms, as no two persons are likely to agree to the temperatures they represent. The table given on p. 182 was made after a very careful study of the appearance of steel in average daylight, when heated to these temperatures.

The tempering temperatures given by the steel-makers should be strictly adhered to, and in the absence of a pyrometer it is advisable to experiment first of all by heating pieces of steel to various temperatures, so as to become familiar with the colour that steel assumes at

these temperatures. Further, it should always be borne in mind that heated objects look brighter in a dull light than in a bright light, and vice versa. It is very instructive to harden pieces of steel at various temperatures and then to break them in order to compare the fractures. It will be noticed that the piece breaks the easiest that has been hardened at the highest temperature.

While it is advisable to use a pyrometer, with careful observation and close application a workman can soon become an expert in the hardening and tempering of steels without the assistance of such an instrument. It should also be taken into consideration that even if a pyrometer is used, it only registers the temperature near its end, and unless the furnace is closely watched, there can be a great variation in temperature at different points inside the furnace.

The proper hardening and tempering of steel is an " art " only acquired by constant observation, and the best results can only be achieved by great care in obtaining, as near as possible, the temperatures aimed at, as negligence in any form can only result in poor temper and consequently in a poor tool. In heating all tools, etc., they should be placed as near the centre of the furnace as possible, and the furnace doors should not be left open longer than necessary. When a number of articles are being hardened at one time, they should not be placed in a heap, but a little space should be left between each, as, if they are in a mass, the outside ones cool much quicker than those on the inside. Steel should not be left in the fire or furnace any longer than is necessary to heat uniformly through, and if it is heated in a fire, it is best to gradually heat right through, and then bring up to the required temperature quickly, without undue forcing.

If steel for hardening is heated in an ordinary smith's fire, the blast should not be allowed to blow on the article, and the fire should be as clean and as high as possible. The steel should also be covered in with fire, as the oxygen in air, if allowed to play on the heated steel, causes surface decarburation or softness.

If dies are heated in a smith's forge, the die face should be uppermost, with the face well covered ; moreover, the die should be turned round frequently in order to obtain uniform heating. Over-heating should be avoided, as this decreases the strength of the material, and also causes cracking and warping. Uneven heating causes uneven expansion, which is the primary cause of distortion in hardening. Uniform temperatures prevent varying strains being set up on quenching, and this is the secret of successful hardening. If using a pyrometer, place the end as near as possible to the work being heated, in case the temperature is not even, throughout the furnace.

A magnet is sometimes used for ascertaining if the heat is correct. A small magnet is attached to a brass rod, and when the temperature is reached at which plain carbon steel hardens, it becomes non-magnetic. It should, however, be noted that this only applies to plain carbon steel.

A number of small articles can be effectively hardened at the same time by placing them in a piece of wrought-iron pipe, closing up one end and heating in the smith's fire, which has been built well up round the pipe. It should be remembered that steel, when hardened, corresponds to the highest temperature it has attained, no matter whether it is quenched at the temperature or allowed to cool slightly to the correct temperature.

The impressions of dies, etc., can be protected from oxidation and consequent burning away during the process of hardening, by covering them with a thick paste of linseed or cotton-seed oil and powdered bone. It may be noted also that a small tool does not require as much heat as a larger one, since it cannot absorb so much, and this also applies to tools with teeth.

Quenching.—Whatever is used as a quenching medium, it is important that it should be kept as near as possible at a constant temperature. The following is a list of the liquids used for quenching purposes arranged in order of merit :

1. Sprayed water.
2. Brine.
3. Water.
4. Water with oil on top about 2 inches deep.
5. Warm water about 35° C., or 100° F.
6. Oil.

The following rules should be observed when quenching is being performed : For general hardening purposes using water, the temperature should be 50° to 60° F., and the larger the quantity of water the better. When hardening small tools in oil, in very cold weather, it is advisable that the chill should just be taken off the oil. If using brine, it should be just strong enough to float a raw potato.

Large and intricate articles, as well as dies, should be quenched in water, and when they have become black-hot, quickly plunged in oil, as this relieves the strains, and also minimises the risk of distortion and cracks. Articles with holes should always be quenched with the holes uppermost, as if they are underneath the steam which is generated accumulates in the holes, stopping the quenching medium from entering.

Long slender tools should be quenched in a vertical position, a warm bath being used to obviate distortion. To quench gauges or screwing dies, protect the body, and allow a stream of water to pass through the hole, as this is the most effective way to prevent warping.

The thickest part of the article should enter the bath first, and it is inadvisable to allow the job to drop to the bottom of the bath until it is completely cooled. Since there is always a risk of tools or other articles with holes cracking, any other holes not requiring to be hardened can be filled up with fireclay. What is termed " black heat " is that temperature at which, when the article is being quenched, hissing just ceases. If iron wire filled in with fireclay is put round places not requiring to be hardened, these spots will remain soft.

Flat press tools should be quenched in a vertical position, moving up and down to allow the quenching medium to circulate well, and they should be immediately withdrawn when the temperature has fallen to a "black heat," and allowed to cool off in oil. Never grip a heated article with cold tongs, as this usually results in surface cracks. Steel which has been overheated should be again heated to the correct temperature, and allowed to cool in dry lime, sand, or hot ashes.

Tempering.—For tools which require hardening and tempering throughout, if salt, lead, or oil tempering baths are not available, then the surface of the hardened article should be well cleaned with emery cloth, and tempered on a heated plate, until the desired temper colour is reached. If the plate is heated by gas, the temperature can be better controlled than otherwise.

The articles to be tempered should be placed face uppermost, so that the heat runs from back to front. If tools having fine projections are being tempered, a little oil should be smeared on the projections two or three times, as this will prevent such parts being heated to a greater extent than the other portions.

Tools which only require to be hard at the cutting edge, such as chisels, drills, and the like, should have the cutting edge quenched about $\frac{1}{2}$ to $1\frac{1}{2}$ inches up, the article being moved about slightly to avoid a sharp line; the edge is then quickly cleaned up with emery, or other means, and the heat in the body of the tool allowed to run down, until the cutting edge assumes the colour required, when the article is then cooled right off.

High-speed steel is heated gradually to a full bright red (900° C.), and then quickly to a white heat, 1,250° C., being then immediately cooled off in a cold blast, or allowed to cool to a dull red, after which it is quenched in oil.

Annealing. The most effective way of annealing small tools is to place the articles in an iron box, preferably lined with fireclay, the lid being also filled round the crack with fireclay, to exclude air. The box is then heated up to the necessary temperature, allowing the heat to penetrate right through, after which it is allowed to cool down as slowly as possible. The vacant spaces in the box can perhaps be better filled with charcoal, lime, or sand, and a little resin placed in the box has a good effect.

Case-hardening.—Articles to be case-hardened require to be placed in air-tight boxes, and packed with a good carburising material, the edges of the lids being luted with fireclay, to make the boxes air-tight. The bottom of the box is first covered with a layer of carburising mixture, then a row of articles to be case-hardened, each a little distance apart, is placed in position, another layer of mixture is added, then more articles, and then so on until the box is filled.

The box is then heated up to a temperature of 850° to 900° C., and allowed to remain at that temperature for four to eight hours, according

to the depth of hardening required. It is then allowed to cool slowly. The box is then unpacked, and the articles re-heated and quenched in water or oil. The use of water gives a harder surface, but with oil the risk of distortion is lessened.

Wood charcoal and barium carbonate, 60 parts charcoal and 40 parts carbonate, make a splendid case-hardening media, 20% fresh mixture being added each time it is used.

A Few Practical Hints.—When making a chisel or any tool that has to be subjected to hammering, heat the shank end first and cool in oil; then when the cutting end is being heated for hardening and tempering the shank will remain hard enough to withstand the shock without burring.

Warm up the top end of all blanking and piercing punches to a dark blue after they have been tempered; this will permit of them being burred over when finally fitted.

If it is required to bend a file in order to get at an awkward part, heat it to a dull red, bend it to the desired radius; then re-heat it to a bright red and quench in water. The pretty, mottled finish which is seen on some tools is obtained by skin-hardening with cyanide or ferrocyanide of potassium and quenching in brine.

Die Setting and Testing.—The setting of a press tool for operating requires care and precision. It must always be borne in mind that if the tool is wrongly set or out of alignment, one operation under power can ruin the whole tool and reduce it to scrap. A tool is always mounted into the press in an assembled state, *i.e.* with the punch entered into the die. The press is pulled round with the tommy bar until the ram is at the lowest part of the stroke, and the ram screw adjusted until the tool will just pass underneath, or if it is too low, it is built up with a bolster. The spigot cap is lightly bolted into position and parallel strips placed between the underside of the punch and the top of the stripper. The press ram can then be screwed down to ensure the top of the tool being in direct contact with the bottom of the ram. The spigot-retaining cap, or screw in the case of a hard press, is then tightened up. Clamps are now placed on the bottom part of the tool, but at first they are only lightly bolted down to the press bed. The parallel strips are now removed, and the press pulled round by hand; at the same time the amount by which the punch is entering the die is carefully checked. When all appears clear, the clamp bolts holding the tool down are given another turn, and the press pulled round again by hand, and so on until the clamp bolts are very tight.

The safest way, now, is to take a couple of turns upwards on the ram screw, to bring the punch clear of the die when it is being operated. In the case of a blanking tool, the material can now be inserted, and the catch tripped so that the tool can operate for one blow. In all probability, the punch will not hit the material, and a slight turn downwards must now be taken on the ram screw, and the press again operated, the process

being repeated until a blank is struck. To the experienced man the first blank tells him much about the tool. If it is a good clean blank, without burr, the tool can be regarded as satisfactory. Should the blank show bright polished spots, giving one the impression that it has been forced through the die, then there is insufficient die clearance. Whenever the blank shows this fault, the die must be " cased " by grinding or a stone. If the blank shows a heavy burr all round without any polish, the die clearance is too much. When the blank shows a burr on one side, and polish on the other, then the tool is out of alignment, and it requires re-setting in the press.

CHAPTER 9

PLASTIC PROCESSES

THE most important process in the plastic industry is that of moulding, which consists essentially of placing the moulding compound, either thermoplastic or thermosetting-plastic, in a mould and supplying sufficient heat and pressure to force the charge into the cavity and thus to take the shape of the mould. Variations of this elementary process have been developed, but the three essentials are: (*a*) pressure, (*b*) heat, and (*c*) the mould or cavity. The two former may be considered as standard for all types of plastic equipment, although sometimes it is more convenient to incorporate a special heating device in the mould itself, this last being the special or particular part of the equipment, being designed according to the requirements of a predetermined article.

Presses.—The mechanically operated presses of the crank type, such as are used so extensively in the press department of a firm engaged in sheet-metal work, are not really suitable for moulding plastics, due to the rapid change in velocity at the lower end of the stroke. This does not allow sufficient time for the gases to escape from the fluxing plastic compound, and so the mouldings are not satisfactorily cured. On the Continent, and especially in

Fig. 192.—Double-crank moulding press. (Benrath M/C. Tool Co., Ltd.)

Germany, many devices have been invented to overcome this disadvantage and, amongst others, the double crankshaft press seems to be very popular. Fig. 192 shows a press of this type, the relative advantage of the movement operated by the single crank and that obtained with the toggle crank being shown in Fig. 193, in which the centre diagram (*a*) shows the movement of a plunger operated by a single crank, (*b*) on the right, shows the movement produced by a toggle crank, and (*c*) on the left, a double-crank arrangement having an even better result than the toggle crank. One advantage of the mechanical press is that when used with electrical heaters it offers a self-contained transportable unit suitable for firms making only a few types of

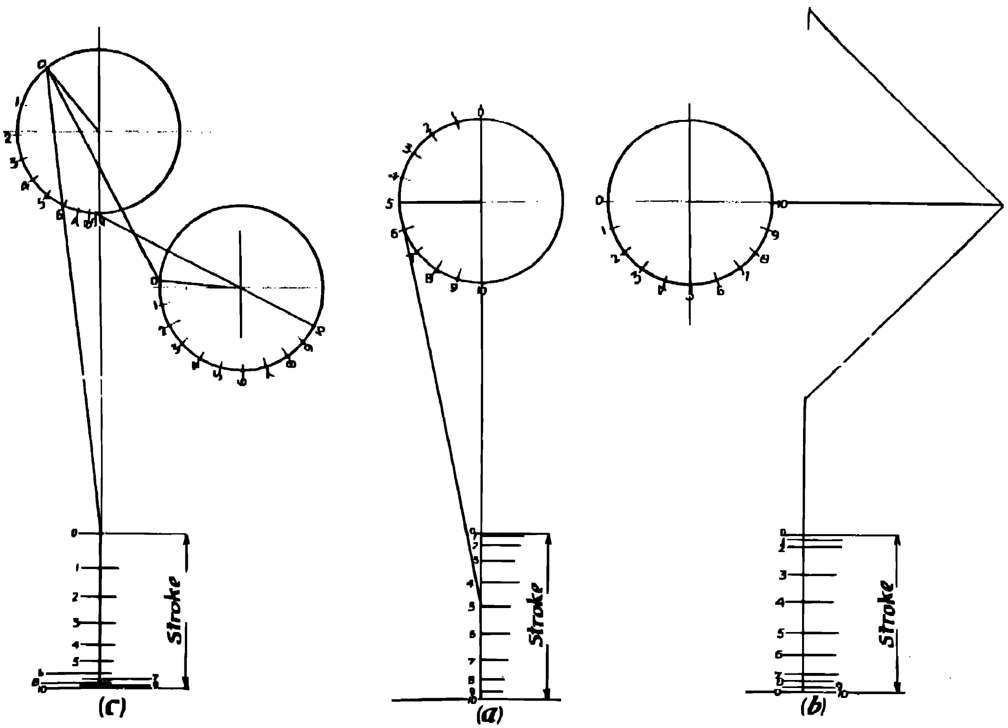


Fig. 193.—Different types of crank actions.

mouldings. Further, it is claimed that, due to the constantly increasing pressure built up by the particular movement, the moulding is free from gas inclusions. Owing, however, to the simplicity and desirable operating characteristics of the hydraulic press, this type has become, with the exception of the above-mentioned mechanical press, the standard kind for plastic moulding.

The principle of hydraulics was first enumerated by Pascal, a Frenchman, who made this statement : " If a vessel full of water closed in on all sides has two openings, the one a hundred times bigger than the other, and if each be fitted with a piston of sliding fit, then one man pushing at the small piston will exert a force which will equal that of one hundred

men pushing the larger piston and will overcome that of ninety-nine." An Englishman, Joseph Bramah, however, invented the first hydraulic press. Fig. 194 illustrates the principle, and shows a simple hand-operated pump and press. Since the area of the small ram is 5 square inches and that of the larger one is 40 square inches, a weight of 2·5 tons on the small ram supports a load of 20 tons on the larger one. A liquid, being practically incompressible, will transmit power and energy along a pipe from the pump to the ram of the press as shown, and thus, by providing a suitable motive force to drive the pump, it is possible to build up sufficient pressure for moulding, usually between 1,000 and 3,000 lb. per square inch. The general arrangement of a single-pressure system such as is used for small presses is shown in Fig. 195. Water is fed from a tank to the pump, which is driven by any suitable means such as an electric motor, and which has usually three cylinders with cranks set

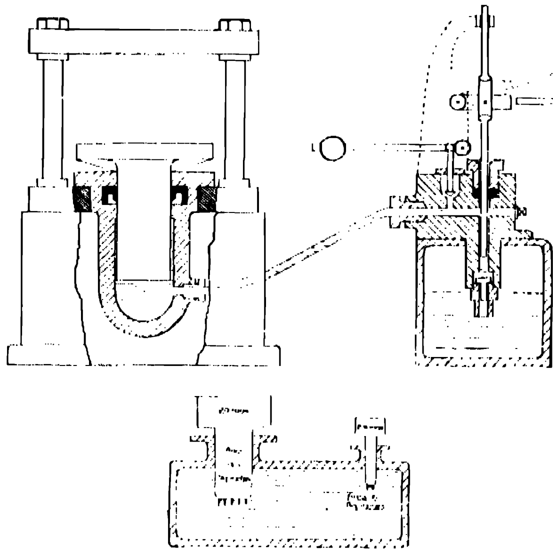


Fig. 194.—Principle of hydraulic press.

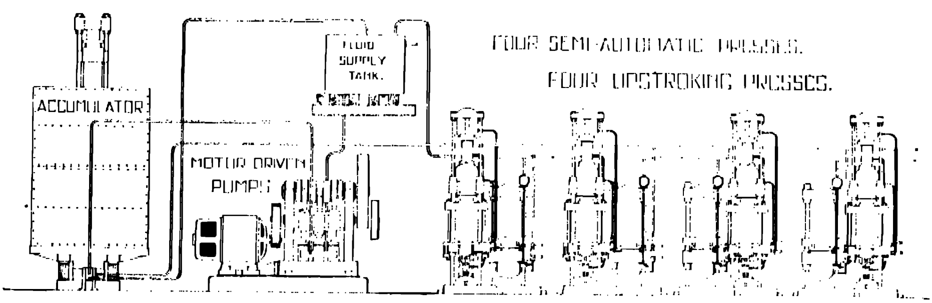


Fig. 195.—Lay-out of hydraulic moulding plant. (Bradley & Turton, Ltd.)

at 120° to ensure an even supply of pressure water, this type of pump running at 100 r.p.m. The term *water* is used, but various compounds are added to the water, or another liquid such as lubricating oil may be employed in a hydraulic system in order to overcome the disadvantage of corrosive and frictional influences possessed by water. The water is driven into the supply pipe, hence to the accumulator, which not only acts as a reservoir for the pressure water, but also regulates the

pressure of the system. A small self-contained automatic hydraulic pump with its accumulator is shown in Fig. 196.

The accumulator consists of a cast-iron cylinder, heavily loaded, sliding on a vertical ram which is secured to the floor, although in newer designs instead of solid weights the cylinder is forced down by pneumatic pressure, and thus there is not the need for such a large unit. The method of calculating the intensity of pressure exerted by the accumulator is to divide the combined weight of the cylinder and loading in pounds by the area of the ram in square inches; thus, if the diameter of the ram is 8 inches, its area is 50·266 square inches, and if the load is 100,532 lb. the operating pressure would be 2,000 lb. per square inch.

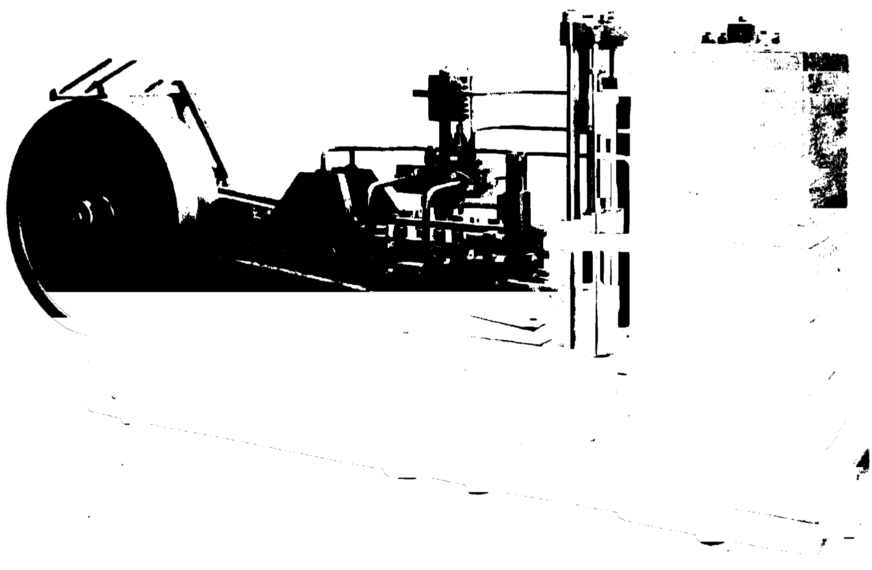


Fig. 196.—Self-contained automatic hydraulic pump with accumulator control. (Bradley & Turton, Ltd.)

In the case of the pneumatic loading, the intensity of pressure may be found by multiplying the pressure of air, usually 200 lb. per square inch, by $\frac{D^2}{d^2}$ where D is the diameter of the air cylinder and d the diameter of the ram. The movement of the accumulator cylinder operates a pump-control mechanism by shutting off the power or by-passing the water when it reaches a certain height and starting the pump when the amount of water drawn off causes it to drop below a predetermined level. Should by-passing be the method used, then a device must be incorporated to prevent the valve being in a constant state of fluctuation, called "hunting," thus allowing water only slightly below the maximum pressure to pass into the suction tank. It can be understood that as

the pressure is uniform throughout, the force is directly proportional to the areas of the ram and pump; and since the movement is inversely proportional to the areas, a considerable waste of high-pressure water would occur if the single-pressure system was used in an installation consisting of a number of presses. Hence, there has been developed a dual-pressure system which is now extensively used even in comparatively small shops.

The dual-pressure system involves the use of two sets of pumps or, alternatively, a two-pressure system pump, and two accumulators with interlocking control valves, so that the press ram is allowed to operate, using low-pressure water until it actually reaches the powder, when the high-pressure water is admitted and the stroke completed. The low pressure is generally 200 lb. per square inch. A practical example will illustrate the economy of the dual system. If the weight of the platen and ram, etc., is 600 lb. and the diameter of the press ram is 12 inches and the stroke 10 inches, then water at 5·3 lb. per square inch would just move the ram in an up-stroke press, so that 200 lb. per square inch would be ample to give rapid movement. If the high pressure had been used, then 1,120 cubic inches of water at, say, 2,000 lb. per square inch, would have been used, which obviously represents valuable energy lost. Assume that the press is rated at 100 tons capacity and takes one minute to complete the stroke and that it is used every four minutes, the horse-power supplied is:

$$\frac{2{,}000 \times 112 \times 10}{4 \times 33{,}000 \times 12} = 1{\cdot}42 \text{ h.p.}$$

Now the power required when moulding may be divided into two parts, that for moving the ram, platen, mould, etc., and that required for the actual squeezing operation. Thus if the weights be as before, 600 lb., and the final pressure be 100 tons built up in the last $\frac{1}{4}$ inch of the stroke, the work to move the parts will be $\frac{600 \times 9\frac{3}{4}}{12} = 488$ foot-pounds of work done in nearly one minute. The work required for the last $\frac{1}{4}$ inch will the average pressure in pounds multiplied by the distance in feet. This equals $\frac{2{,}000 \times 112 \times 1}{2 \times 48}$ foot-pounds or 2,334 foot-pounds. The horse-power used, therefore, equals $\frac{488 + 2{,}334}{4 \times 33{,}000} = {\cdot}0214$ h.p., or only 1·50% of the available horse-power, neglecting frictional and pump losses. If low-pressure water had been available at 200 lb. per square inch for the $9\frac{3}{4}$ inches of movement the total horse-power would become:

$$\left[\frac{\left(\frac{200 \times 112 \times 39}{12 \times 4}\right) + \left(\frac{2{,}000 \times 112 \times 1}{48}\right)}{4 \times 33{,}000}\right] \text{h.p.}$$

$= {\cdot}173$ h.p., or the efficiency is now just over 12%.

An alternative method of providing the high-pressure water is to employ an intensifier instead of the high-pressure pump. The intensifier injects a charge of high-pressure water into the cylinder, obtained by delivering low-pressure water into the larger of two differential hydraulic cylinders locked together, the high-pressure charge being delivered by the smaller cylinder to the press ram. The danger is that if insufficient water is injected in the first charge, then the moulding will be spoilt whilst waiting for the intensifier to reset. This applies more particularly to the thermo-setting plastics.

There are various other ways for reducing the long lengths of piping operating at high pressure, of which one that has proved very successful in practice is found in the "pre-filling down-stroke" press, Fig. 197. In this press, water at a very low head (sometimes called "slack water") is used to fill the cylinder whilst it is dropping, then as it passes a tripping device, the cylinder is sealed and the high-pressure water delivered, so that only a small amount of high-pressure water is used. This results in a great saving in the size of equipment and also in the running costs. Push-back cylinders are fitted at the sides to push the platen up after the curing of the moulding, these being interlocked to prevent the ram falling until the side-ram exhaust valves are open. Variable-stroke pumps are used in self-contained units, but these have not become generally popular.

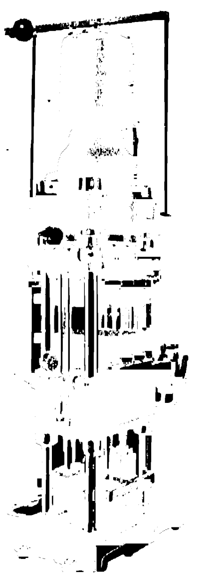


Fig. 197. Pre-filler type of down-stroke hydraulic press. (Bradley & Turton, Ltd.)

Pipe Work.—When fitting high-pressure pipe-lines, it is advisable to use pipes with a wall thickness of the size above the bore, thus for 1¼-inch bore the thickness would be such that a 1½-inch British Standard pipe thread could be cut on it. Only solid drawn-steel tube should be used, and the joints should be made with the two- or four-bolt type of flange with a copper washer acting as packing.

The hydraulic press is ideal for plastic moulding in that it is simple in construction, and the pressure can be regulated and is constant throughout its stroke, this latter being very important, because as the heat fluxes the powder, the ram follows the shrinkage until the mould is closed. The simple up-stroke press shown in Fig. 198 illustrates the general type of construction, four strong pillars acting as guides for the moving platen and providing the necessary adjustments for the alignment of the head. The ram is smooth and round, and is usually hollow to reduce weight, and copper-plated to prevent corrosion. Leather packing rings are employed to prevent the pressure water from escaping, and these must be inserted with great care and chosen for durability rather than with regard to the price. The U-shaped ring is used extensively; since the water under pressure in the cylinder tries to force its way out,

but on coming into contact with the washer it immediately flows to the inside of the " U," thus forcing it both to the cylinder and to the ram, so forming a water seal, any increase in pressure serving to increase the efficiency of the seal. Inlet and outlet valves are usually arranged in one body, and the simple lever-operated screw-down type is employed, as these give the best service with the minimum amount of trouble. Pull back rams are sometimes necessary for up-stroking presses in order to ensure the break-away of the mould.

Down-stroke presses were viewed with disfavour when first introduced into this country from America, but are now used extensively, as they possess several advantages. Thus, the working platen is always at the same height; the prefilling type previously described reduces operating costs and a separate ram may be fitted to lift the ejector frame without the usual rods, which may hamper production, yielding the additional advantage that it is not necessary to wait until the press has nearly finished its stroke before ejection takes place.

Angle presses provide independently operated moving platens in two directions perpendicular to each other, the horizontal ram being used to hold together the halves of a split-type mould.

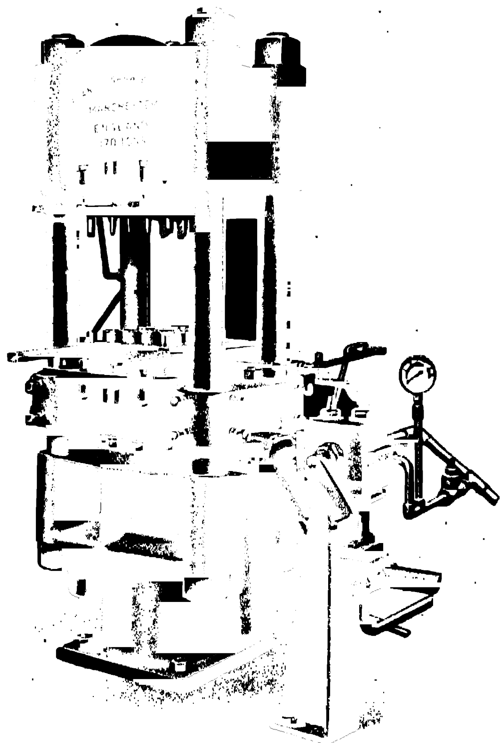


Fig. 198.—Up-stroke type of hydraulic press. (Francis Shaw & Co., Ltd.)

All hydraulic presses are rated in tons of total pressure, and this may be obtained by multiplying the cross-sectional area of the ram by the intensity of the pressure in the hydraulic system. To this must be added the weight of the ram and platen, etc., if it is a down-stroke press, while in an up-stroke press it must be subtracted to get the effective pressure (Table I).

Injection moulding machines used for thermoplastics may be operated by hand, air, or electricity, and consist of one fixed platen and one sliding platen, one-half of the mould being attached to each platen (Fig. 199). A hopper is provided, which allows the powder to fall into the cylindrical heating chamber, which is surrounded by an electrical element adjusted so that the charge is in a plastic state by the time the

TABLE I.—PRESS CAPACITY

Diameter in inches.	Area in square inches.	Pressure (lb. per square inch).								
		1,000	1,250	1,500	1,750	2,000	2,250	2,500	2,750	3,000
1	·7854	·35	·438	·525	·612	·70	·788	·875	·96	1·05
2	3·142	1·4	1·75	2·1	2·45	2·8	3·15	3·5	3·85	4·2
4	12·566	5·6	7·0	8·4	9·8	11·2	12·6	14·0	15·4	16·8
6	28·271	12·613	16·25	19·0	22·6	25·23	28·80	31·5	36·15	37·84
8	50·265	22·4	28·0	33·6	39·0	44·8	50·4	56·0	61·6	67·2
10	78·54	35·0	43·7	52·5	61·3	70·0	78·7	87·5	96·2	105·0
12	113·1	50·45	63·0	75·7	88·3	100·9	113·45	126·12	138·7	151·35
14	153·94	68·72	85·0	103·0	120·2	137·45	154·62	171·8	188·9	206·17
16	201·06	89·6	112·0	134·4	156·5	179·2	201·6	224·0	246·4	288·8
18	254·47	113·6	137·0	160·4	193·8	227·2	250·6	274·0	297·4	340·8
20	314·16	140·0	175·0	210·0	245·0	280·0	315·0	350·0	385·0	420·0

previous charge has been cured. At one end of the chamber is fitted a plunger so that when the charge is hot and the mould empty a movement takes place which first causes the mould to close; the nozzle is

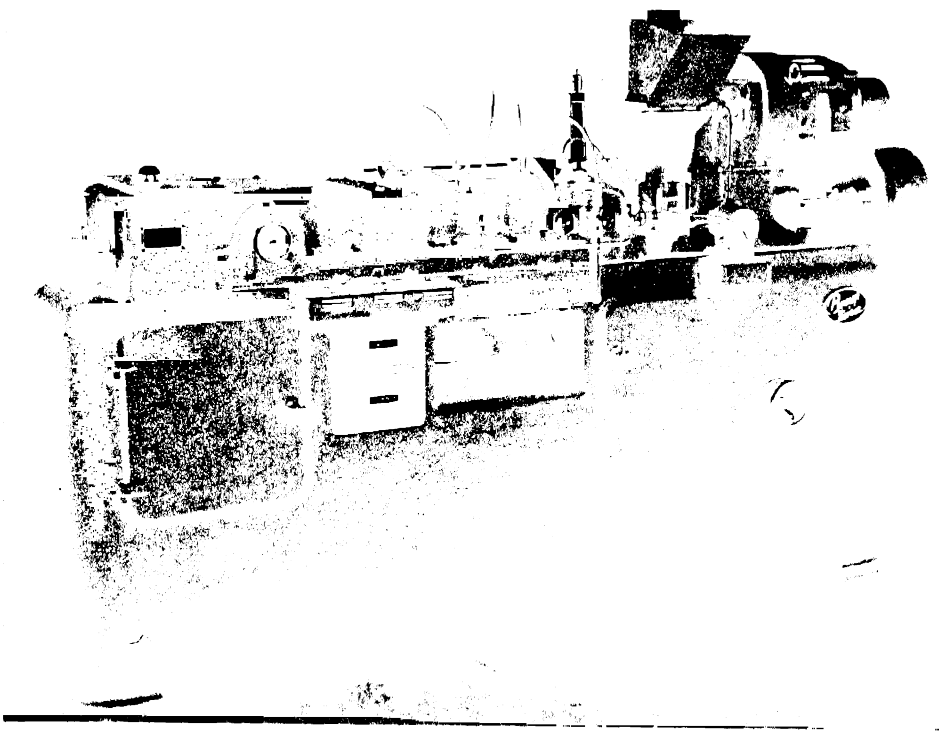


Fig. 190.—Injection moulding machine. (Franz Brawn A.G. & Dowding & Doll, Ltd.)

then brought into contact with the inlet to the mould and finally the plunger forces the charge into the cavity of the mould. At the end of

the cure the movement is reversed, and due to a permanently circulating water system, which keeps the mould comparatively cold, the moulding is ejected without the delay occasioned by the older method. The speed of production is high, but comparatively small articles only are being moulded, although in France, where the method is very popular, larger articles such as battery cases are being produced.

Considerable progress has been made with this type of press, and fully automatic machines are now available for producing fittings with screw threads moulded, either internally or externally. The ejection is effected by an electric motor, switched on at the moment of mould-break, which rotates the threaded member, after which the plunger pushes the component out. Production is limited by the amount of material fluxed per hour, and about 11 lb. per hour is the output of the fully automatic machines.

Fig. 200 shows a light style of injection press.

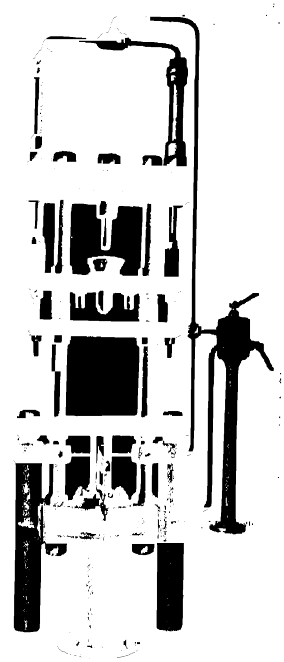


Fig. 200. Light design of injection press. (Francis Shaw & Co., Ltd.)

Heating Methods.—Steam, gas, and electricity are commonly used for heating moulds and platens; although on the Continent hot oils have been also used to some extent. Generally, steam is the best medium, although, if the electrical supply is cheap, it can be used with distinct advantages. Gas has only a limited application, and is generally confined to heating the hot-plates for thermoplastic "dough." Temperature control is difficult with low-pressure gas, but more successful results have attended the efforts to use high-pressure gas.

The steam supply requires suitable boiler plant of sufficient capacity to allow for any expansion of the works, and it must not be overlooked that the larger the installation the lower the cost per unit of steam raised, thus it may pay to use steam for general heating purposes of offices, etc., especially as super-heated steam is not required. The twin-flue Lancashire-type or the Cornish-type boiler is suitable, because of the reserve of steam available against sudden demand. Boilers are rated on the number of pounds of water evaporated per hour, and a boiler working at 170 lb. per square inch is desirable, as this is about the maximum pressure required, as it is reduced to about 150 lb. per square inch at the platens. Suitable pressures and corresponding temperatures are given in Table II. A reducing valve is fitted to the supply side, which affords control of the pressures, and hence of the temperature, while a steam trap is also fitted in order that the condensed hot water can be released and passed back to the boiler. Flexible metallic tubing is the best type of connection for supplying steam to the moving platen, as it is not so liable to burst.

TABLE II.—STEAM TEMPERATURES

Gauge Pressure. (lb. per square inch.)	Temperature. ° F.	Temperature. ° C.	Gauge Pressure. (lb. per square inch.)	Temperature. ° F.	Temperature. ° C.
50	297·5	147·5	130	355·5	179·7
60	307·2	152·9	140	360·8	182·7
70	315·9	157·7	150	365·8	185·5
80	323·8	162·1	160	370·6	188·1
90	331·0	166·7	170	375·2	190·6
100	337·8	169·9	180	379·6	193·1
110	344·0	173·3	190	383·8	195·4
120	349·9	176·6	200	387·9	197·7

Steam is usually supplied to the steel platens through a system of holes drilled through the platen and tapped at each end to take either a ¾-inch B.S.P. plug or the pipe connections as shown in Fig. 201. The holes are kept near the face of the platen to reduce the waste of heat, and baffle plugs are inserted to cause the steam to travel around the whole system. Copper washers are used to ensure a tight joint, and if the mould is deep then two rows of holes are drilled above each other. The figure of 3 to 5 lb. of steam is quoted as a suitable steam supply per square foot of platen or mould exposed.

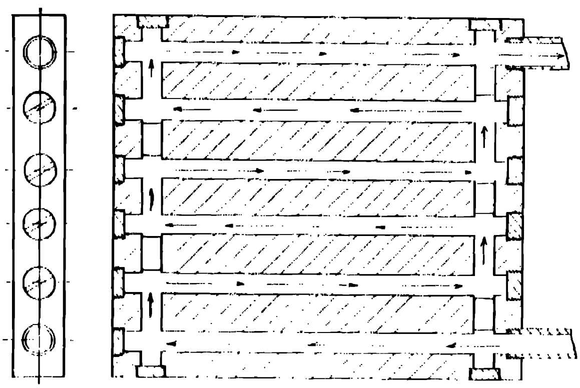


Fig. 201. Steam-heated platen.

Electrical heating is the cleanest method, but its cost has prohibited its more general application, coupled with the disadvantage of a complete breakdown of production if one of the heating elements should burn out. The electrical heating element is usually a flat 20% chrome-steel sheath of standard section, which is filled with a refractory material in which are embedded coils of wire made from 80% nickel and 20% chromium. This wire has the property of offering a big resistance to the flow of electrical current, and thus the necessary heat is generated. Each element is fitted into a groove or slot which has been machined in the platen, Fig. 202 showing a typical arrangement in which the terminals are protected to prevent damage and shock to the operator, the whole system being earthed to yield additional safety. The thin plate is fitted to protect the elements, the number of which is dependent upon the size of plate, 10 watts per square inch of heating surface of the platen being the usual loading. Thermostatic control of the platen is now generally used, the

type of thermostat being dependent upon the supply, either a.c. or d.c., the use of a secondary contactor switch being necessary where the load of the strips exceeds certain wattages. The average thermostat has a maximum making and breaking capacity of 15 amperes, and when the load is above this the switch is necessary. The thermostat is fitted into a hole drilled into the platen as near the centre as possible. The degree of sensitivity can be given as plus or minus 4° F., but all electrical heaters should be lagged to prevent radiation losses.

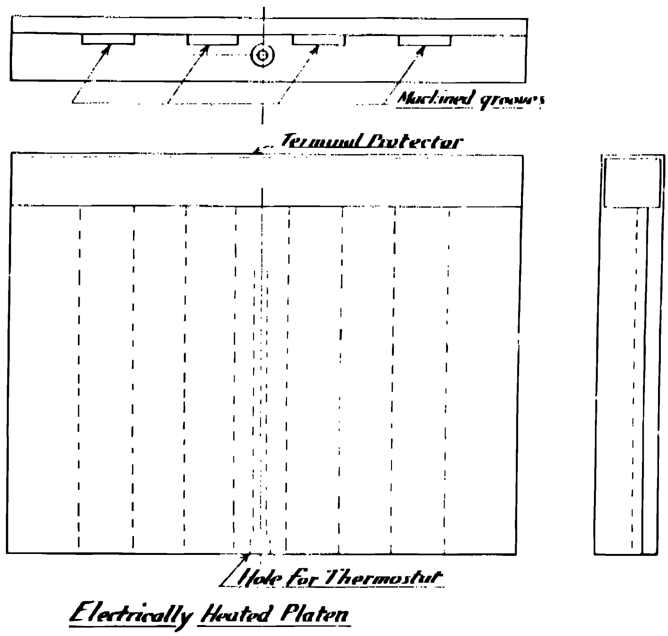


Fig. 202. Electrically heated platen.

Gas is not used to any great extent, due to (*a*) difficult temperature control, (*b*) incomplete combustion, and (*c*) loss of working space (called "daylight"), due to thick platens. The most common type of burner consists of a bar about the length of the platen with a number of holes or slots for the passage of gas. The slots or holes are arranged so that the flames are at about 90° to each other, as this helps to spread the heat and tends to yield a more even temperature, transverse slots being much better than longitudinal ones. Low-pressure gas is used at 4 to 6 inches w.g. (water-gauge) pressure. In high-pressure systems the pressure is 2 to 3 lb. per square inch, the gas being compressed and forced through a felt filter into a small chamber, whence it passes through an orifice at high speed, causing a partial vacuum in the venturi mouth. Air is thus drawn in, the amount being regulated to suit the speed of combustion, and then once the air is regulated the amount of gas may be varied, when, due to the design of the orifice, the air : gas ratio will remain constant, being independent of the gas rate. The consumption is about 25 cubic feet per hour for heating up and 66% lower for normal running. Fig. 203 shows a section through a gas platen. When moulding

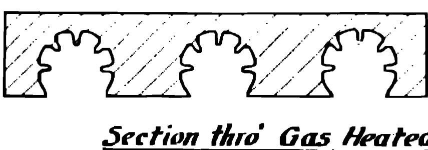
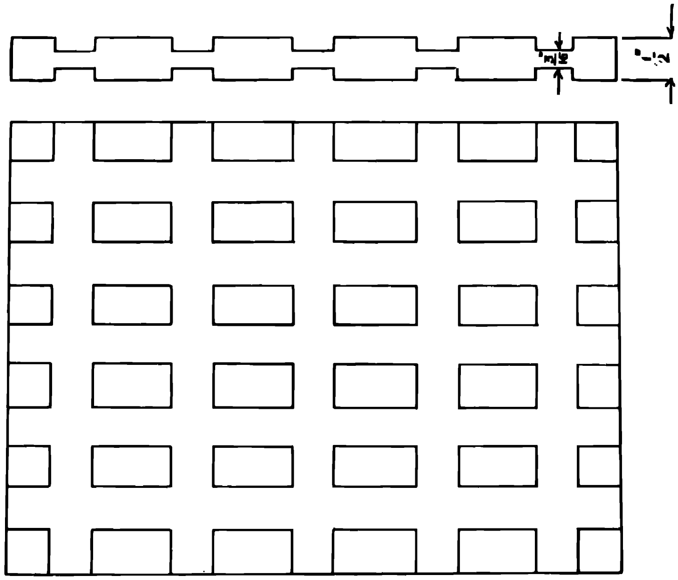


Fig. 203.—Gas-heated platen.

thermoplastic materials, which require a cooling system, then steam only can be used.

Reference has been made to platen heating only, but it is possible to heat the mould by direct means. Thus steam ports may be drilled through the mould and the necessary pipe connections made, but this is only possible when the mould is fixed to the platen, as in automatic production. Likewise, electrical elements are fitted around the moulds or placed in the bolster part of a mould, but gas is rarely used for direct heating.

The loss of heat due to conduction and radiation may be reduced by suitable lagging, but it is not wise to hamper production by paying undue attention to this except in case of electrical heating. The insertion of a heat-insulating material between the platen and the press does much to prevent loss in that direction, and a cement-asbestos board is now made, capable of withstanding the load imposed by the moulding pressure. A machined steel plate with grooves as shown in Fig. 204 will stop considerable conduction, due to the fact that the air lock is a poor conductor. When moulding urea powders and some shades of colour, accurate control of the temperature is vital.



Steel Heat Insulating Plate

Fig. 204. Grooved plate to reduce heat losses.

Moulds.—There are three general types of moulds in use :

(*a*) Positive or plunger type,
(*b*) Semi-positive or positive flash type, and
(*c*) Flash or open type.

These may be designed for single or multiple impression, and further, they may be fixed to the platen with suitable arrangements so as to become either automatic or semi-automatic in operation, or they may be portable or hand operated. For special work the split mould is used. The positive mould, an example of which is shown in Fig. 205, consists of a minimum of three parts, the bolster or chase, the top force, and the

bottom force. There may be more parts to suit the moulding and, although all parts may be used in the forming of the component, the best arrangement is to allow the two forces to control the shape and chase to act as the guide. These moulds are not used to any great extent owing to several inherent drawbacks, chief among which are the large amount of material, the costly machining, the tendency of the powder to cause scoring of the chase, and the necessity for accurate control of the powder charge.

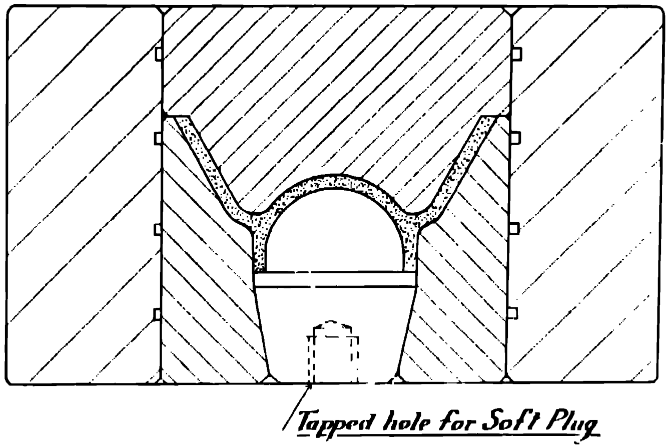


Fig. 205.—Positive mould, showing grooves to reduce scoring troubles.

The scoring trouble may be reduced by cutting grooves as shown in Fig. 205, as this stops a score from going the whole length. Pellets assist the powder control, but except for very short runs or for moulds having a large number of loose pieces which are difficult to hold in place by any other means, they are not used. The semi-positive or positive flash type of mould is shown in Fig. 206, and consists of a top and bottom force. In the

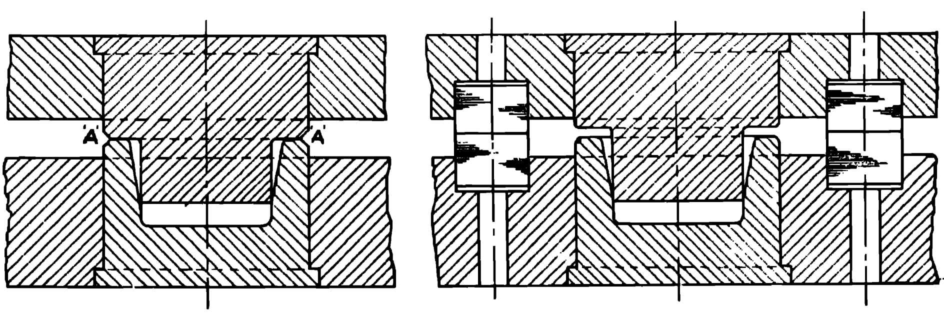


Fig. 206. Semi-positive vertical-flash mould. Surplus material is trapped at AA, but by using pressure pads (as seen at the right) an escape is provided.

top of the bottom force is cut a geometrical-shaped cavity, usually circular, with the mould impression at the bottom of this cavity, which is about $\frac{1}{2}$ inch deep, the sides tapering outwards to the top at 3° to 5°. Into this cavity the top force is followed by a plunger which just fits the bottom of the geometric cavity $\frac{1}{32}$ inch before the press reaches the bottom of its stroke, thus any surplus powder is forced upwards until finally cut off by the top force, and the mould then becomes positive in

action. The modification shown at the right gives the excess material a free "get-away." This is described as the vertical-flash type, because of the direction of the flash.

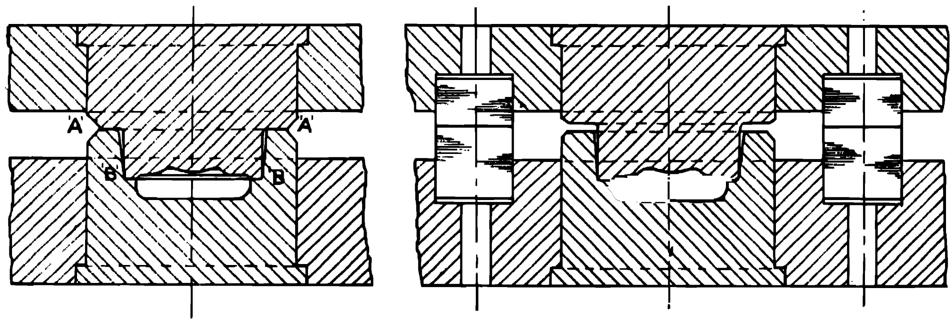


Fig. 207.—Semi-positive horizontal-flash mould. The pressure pads in the right-hand view prevent trapping, which occurs between A and B.

The horizontal-flash type of mould is shown in Fig. 207, but it should only be used when the shape of the mould prevents the former type being used. The former has the advantage of saving costly steel, and

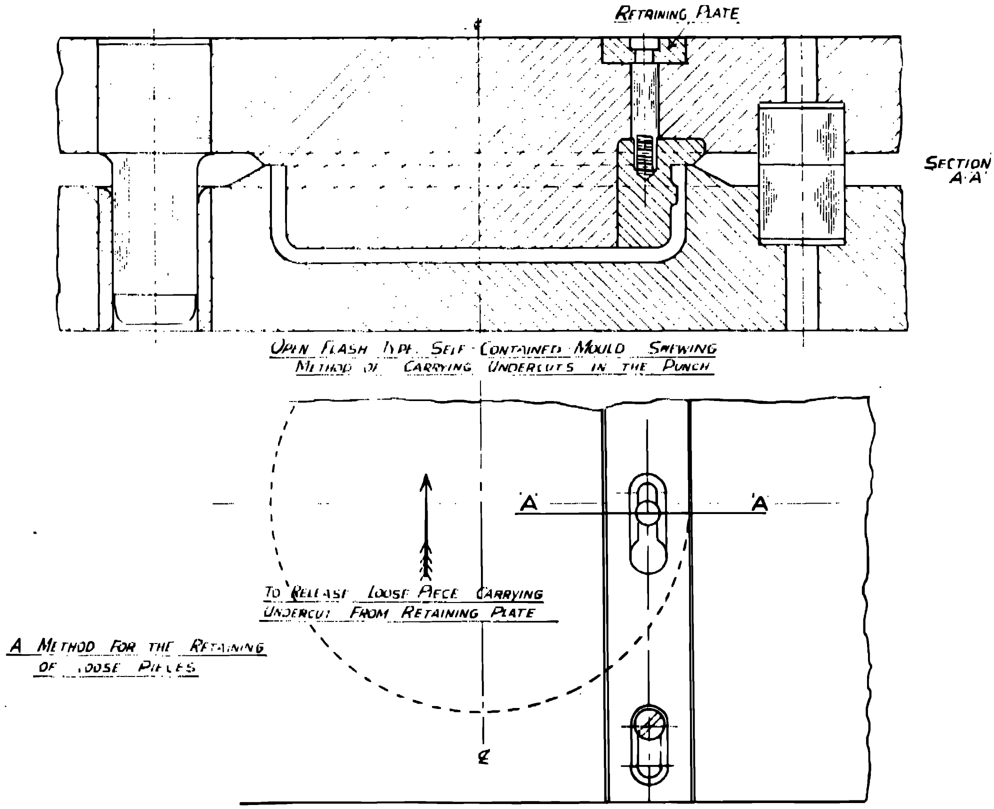


Fig. 208.—Open-flash type of mould.

it also has a longer life, since the faces of the forces do not make contact with one another, and finally there is no pressure on the mould except through the moulding material. These are used either as hand or automatic moulds with single or multiple impressions, although if used as the latter care must be taken to provide an even charge of powder, and with this end in view pellets are generally used. Cleaning of the mould prior to loading may take a little longer, and the cost of making is rather more than that of the flash type, but it is a very useful type, because it affords a cavity for the powder when the moulding is shallow, this being of considerable importance, as the volume of the powder before moulding may be anything from 2·5 to 7 times the volume of the finished article, this being called the "bulk factor" of the powder.

The third important type of mould is the open-flash type, and this consists of top and bottom forces with no loading cavity. The advantages of this type, which is shown in Figs. 208 and 209, may be summarised as

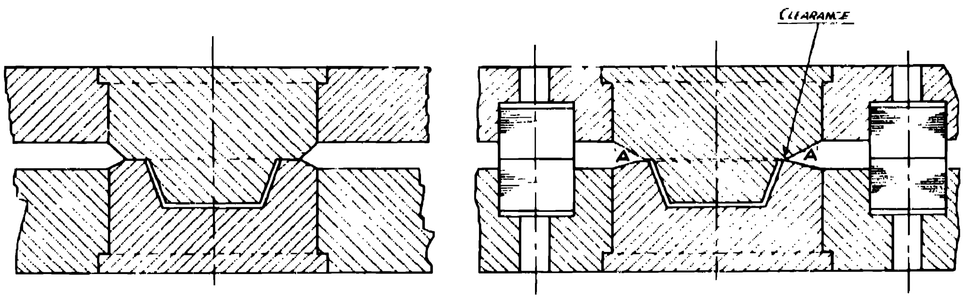


Fig. 209. Flash-type mould, plain and knife-edge designs.

simplicity, open construction, minimum steel required, long life, as no powder can cause serious abrasion by rubbing between the faces of the mould; and it is, therefore, very suitable for multiple impressions. In both flash and semi-positive moulds, locating pins or dowels are necessary to secure correct alignment, as the play, if allowed in the guides of the press, would cause serious damage to the tools. In this respect the practice is similar to that followed in the pillar type of press tool. In order that the thin layer of moulding which is left on the flash line shall be at a minimum thickness, it is necessary that the flash cut-off be kept at a minimum. A danger arises here, however, in that should insufficient powder be charged or the press be allowed to fall with the mould empty the whole force would be taken by the comparatively narrow strip A, $\frac{1}{16}$ inch wide, running around the cavity. This, in all probability, would result in a ruined mould, and to guard against this contingency pads are provided.

Split moulds are necessary when it cannot be arranged for the moulding to be removed by pushing it out by an ejector. A split mould is shown in Fig. 210 in which the lower force has to be parted before bobbin can be ejected. Plate facing p. 204 is an angle press set up with a split mould.

Moulds for the injection type of machine require a conical recess cut on the outside of the force which is attached to the moving plate or platen, and this forms a seating for the nozzle of the material-heating

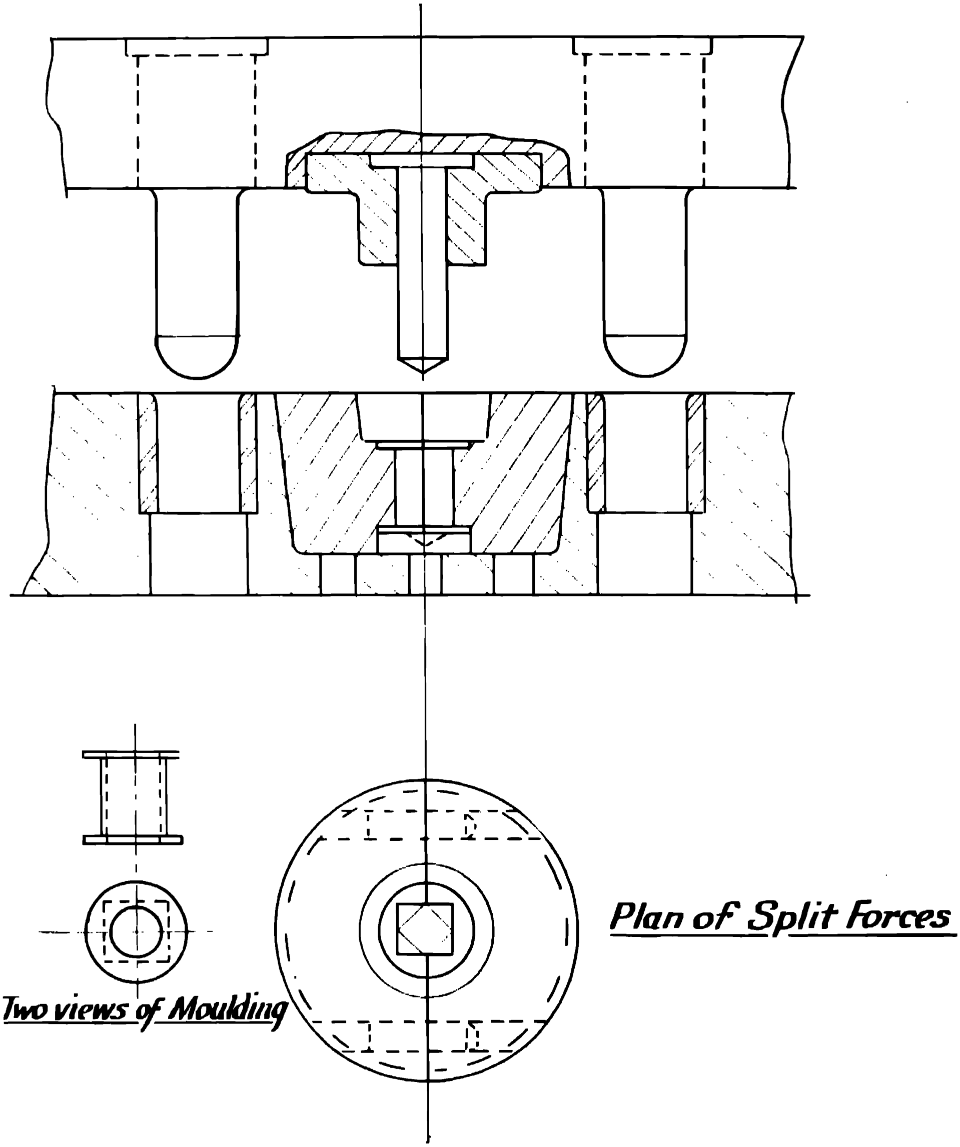


Fig. 210.—Split mould, necessary for removal of piece.

cylinder. Grooves are needed for multiple-impression injection moulds, and these should be as large as possible, with a reduction of the cross-sectional area at the junction of the groove to the impression in order to facilitate removal of the moulding. Frequently these are cut a short

SPLIT MOULD SET UP IN ANGLE PRESS.

way on the side remote from the inlet to the impression in order to give the air more chance of being forced out of the moulding cavity. Articles as ejected from a multiple-impression injection mould are shown in Fig. 211.

It is not necessary that a mould should come under only one of the types, as frequently a single mould will bear features of two or more types, but so long as the distinction of principles is kept in mind, the designer is free to use his ingenuity to the full.

Mould Design.—Before designing a mould there are six facts which

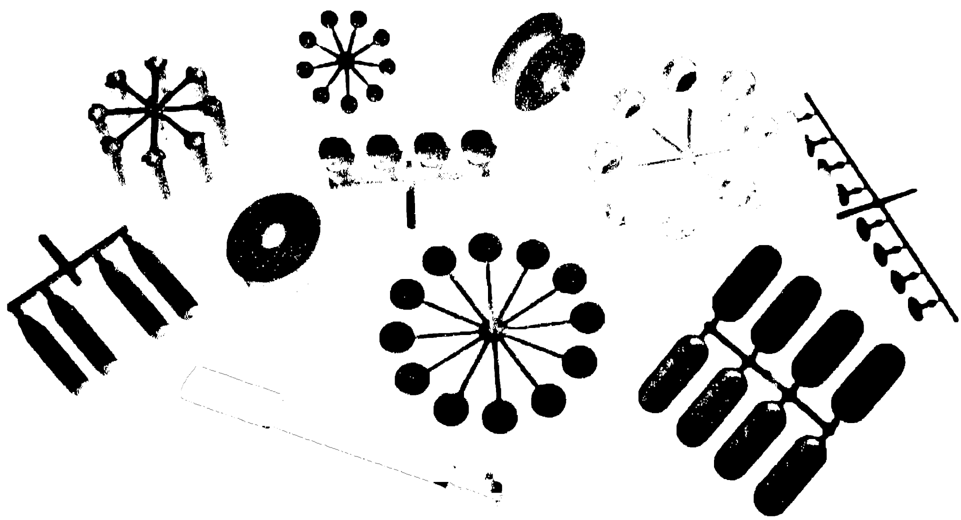


Fig. 211.—Multiple-impression injection mouldings. (Dowding & Doll, Ltd.)

must be known in order that the mould, when completed and in service, will function in the most satisfactory and efficient manner ; these are :

(1) The shape of the piece.
(2) The material of which it is to be made.
(3) The degree of accuracy required.
(4) The kind of finish required.
(5) The rate of delivery.
(6) The total order.

The first two of these will determine the type of mould and, in conjunction with the last two, will fix the number of impressions in the moulds, and the number of moulds to be used, and, if the order warrants it, whether auto moulds shall be adopted. The second and third deter-

mine the shrinkage allowances necessary, and consideration of the first four will indicate the kind of steel to be used and its treatment in the making of the mould. It has been assumed in the foregoing that there is available a number of suitable presses for the job, but should it be necessary to calculate the size of an additional press, then the following method may be employed :

Let P = the pressure lb. per square inch to produce a moulding.
E = the output per hour.
C = the cycle time in minutes (handling and curing).
N = the number of impressions in the mould $= \dfrac{E \times C}{60}$.
A = area of moulding, including the flash.

$$\text{Total pressure} = \frac{N \times A \times P}{2{,}240} \text{ tons.}$$

This is the net capacity, and a safety factor of 50% should be added.

When calculating the pressure required it is usual to take the projected area at the flash line, including the flash area, but some authorities recommend that double the normal pressure be taken when the article is very shallow, as, for example, a tray. The argument for this is that immediately the top force contacts with the powder the whole area is effective and practically no release of pressure can be obtained, due to the very little flow of the powder, whereas in the case of a deep mould the powder flows up the sides and full pressure is not reached until the last squeeze.

Steels for Moulds.—The choice of the most suitable steels to be used in the construction of the mould is a most important consideration, because it must withstand both heat and pressure, take a high polish, be easy to machine, capable of resisting the somewhat corrosive action of some plastics, be non-distorting, have a high tensile strength combined with toughness, take chromium plating, and be of a reasonable price. There are a number of steels of both the case-hardening and the direct-hardening variety which satisfy most, if not all, of these conditions. An approximate analysis of the case-hardening variety, together with the recommended heat treatment, is as follows :

Carbon	·12 to ·15%
Nickel	3·5 to 4·5%
Chromium	1·0 to 1·2%

The following is the correct heat treatment : carburise at 900° to 910° C., heat to 780° C., and quench in oil. Tempering may be carried out at 200° to 250° C. It will be noted that the usual double quench is omitted, as it is claimed that the enlarged crystals from the carburising process forms a strong support against the crushing action of the press. The nickel is included to give toughness, while the chromium yields good penetration to the effects of the heat treatment and a dense structure. Molybdenum is sometimes added to the steel with beneficial results.

Moulds which have been produced by the hobbing process need case-hardening, as, at present, no really successful direct-hardening steel has been found which will " hob " well. Although case-hardening steel is quite good, there can be no doubt that the direct-hardening steels are the best for mould work. Designers often overlook the cost of case-hardening when estimating the cost of production of the mould, although the inclusion of this item will generally bring the total cost to nearly that of oil-hardening steel, although the machining costs of the case-hardened mould, are, of course, lower. The risk of distortion during heat treatment is ever present, and the surface is liable to pitting during the carburising process unless great care is taken.

There are a number of alloy steels with nickel and chromium as the special alloying elements, which are excellent for moulds, and in Table III are given typical compositions suitable for moulds.

The salt-bath method of heating is the best to employ during heat treatment, because it prevents surface blemishes occurring due to oxidation, which, unless great care is taken to produce the correct atmosphere, will occur in the muffle furnace, although the practice of burying in cast-iron dust has much to recommend it. The salt bath gives a uniform temperature, and the work is quite clean and requiring only a minimum polish after quenching in oil. The composition of the salt must be chosen with care; sodium carbonate or sodium chloride causes a de-carbonising action, and it is therefore advisable to use a salt bath compounded to prevent this, sodium cyanide being generally used.

Mould Design Details. From the sample or design, the position of the flash line or the joint line is decided. This should be along the plane of greatest area and should, if possible, be chosen so that the moulding cavity is in the bottom force. It may be necessary to make the flash line in two places parallel to each other or even at an angle to one another. The following features should be avoided where possible:

(1) Deep holes of small diameter; about two diameters deep is good practice, unless there is a big taper; or a large diameter may be somewhat deeper in proportion.

(2) Deep cavities with no taper or " draw "; in some work ·001 inch per inch is allowed, but, wherever possible, a much greater angle should be used.

(3) Holes and indents perpendicular to the line of press.

(4) Holes oblique to the line of press.

(5) More than 32 threads per inch or smaller than 2 B.A. on screwed parts.

(6) Unequal bulk; as this increases the danger of warpage, increases the curing time, and is often a waste of material. Arrange, where possible, for the wall thickness to be even in section commensurate with the strength required. About $\frac{3}{32}$ inch is the minimum for average work, but for heavier parts and when using fabric-filled powders, $\frac{1}{4}$ inch thickness of wall may be allowed.

TABLE III.—APPROXIMATE STEEL COMPOSITIONS AND HEAT TREATMENTS

	Carbon.	Manganese.	Nickel.	Chromium.	Molybdenum.	Vanadium.	Hardening °C.	Temperature. °C.	Max. St. (tons).	Izod (ft.-lb.).	Remarks.
1	·28 ·35	·35 ·6	4·0 4·5	1·0 1·5	·2 ·4	—	820–830 Air	250	108	15–19	—
2	·28 ·32	·45 ·7	3·25 3·75	·6 ·9	—	—	820–830 Air	250	75	60	—
3	·25 ·32	·35 ·6	3·75 4·5	1·0 1·5	·65 apt.	·25 apt.	820	250	100	15	—
4	2·0 2·25	·3 ·5	·35	12·75 13·25	—	·15	930–960 Oil	200	—	—	Suitable for master hob.
5	1·5 1·6	·3 ·5	·35	12·25 12·75	·9 1·0	·9 1·0	900–960 Oil	250	—	—	For large moulds.
6	1·5 1·6	·3 ·5	·8 1·0	15·0 16·0	·75 ·95	·75 1·0	950–1,000 Oil	250	—	—	For large moulds.
7	·25	·45	3·05	1·25	·25	—	830 Oil	500–600 Oil	70	55	—
8	·30	·5	3·4	·75	—	—	830 Oil	560–660 Oil	61	69	—
9	1·2 1·3	·45	3·95	1·25	·25	—	820 Air	250	—	—	—
10	2·25	·75		·5 ·75	—	Trace	830–840 Oil	250	—	—	—

(7) Undercuts, or projections or recesses which do not allow one or other of the forces to be withdrawn in a straight line; these require loose pieces and entail much extra time in the setting up of the mould, which must, moreover, be hand operated.

Occasionally it is necessary to accommodate loose pieces in a mould, and two methods for holding these are shown in Fig. 212. When using these loose parts, the additional flash has generally to be removed, and the piece must be polished to ensure a neat article.

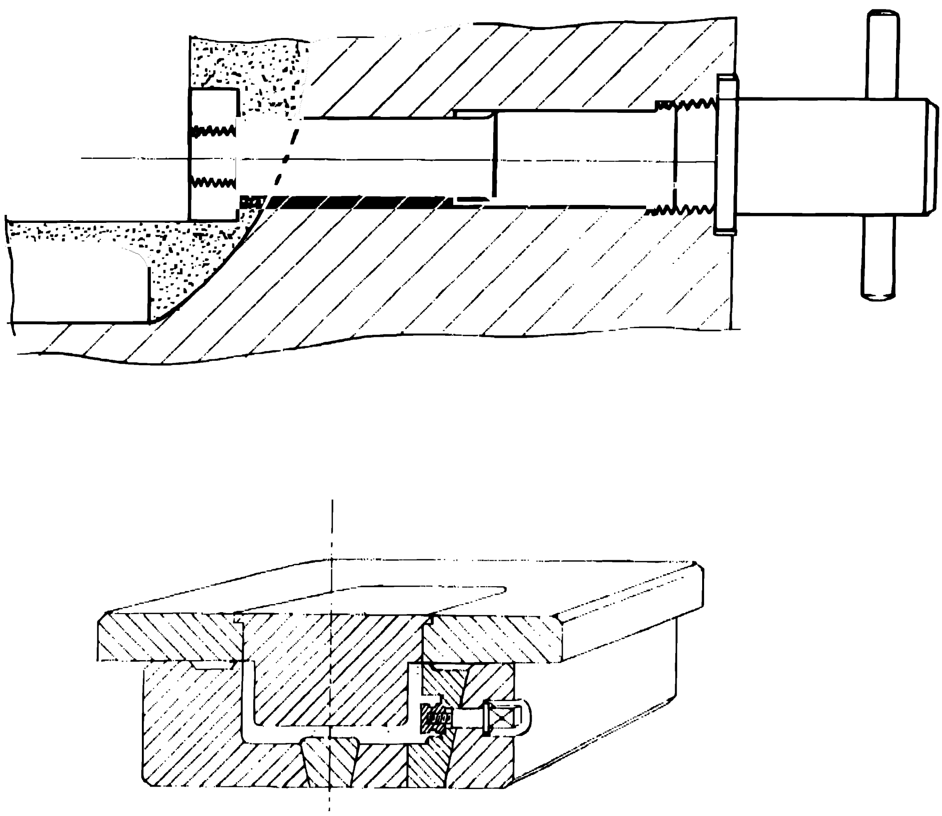


Fig. 212.—Holding loose pieces in mould.

Shrinkage of Plastic Materials.—The shrinkage of the plastic materials varies, but an average of ·006 to ·008 inch per inch may be allowed; this, however, should be verified for accurate work. The mould must be designed to cater for this loss, but the problem of the thermal expansion of the steel has also to be taken into account. This amounts to ·0000061 inch per inch per ° F., so that if the shop temperature is 65° F., and the moulding temperature 365° F., then for every inch at normal temperature the mould has increased by ·0000061 × (365 − 65) = ·00183 inch, and this must be taken into account when dimensioning

the drawing. It is possible to maintain a tolerance of plus or minus ·002 inch at right angles to the moulding line, but plus or minus ·005 inch is more usual, whilst in the moulding line a tolerance of plus or minus ·008 inch should be allowed. Should a metal insert be placed in a moulding then allowance must be made for the piece of metal when calculating the shrinkage, allowing for its thermal expansion.

The minimum wall thickness of the mould may be calculated from the formula governing the design of cylinders subjected to internal pressure, *i.e.*:

$$t = \frac{dP}{2f_t}$$

where t = Thickness of wall in inches,
d = Diameter of cylinder in inches,
P = Pressure in lb. per square inch,
f_t = Tensile strength of the steel.

A factor of safety of 8 is usually allowed, so that if a steel of 50 tons per square inch strength be used: for a diameter of 3 inches and a pressure of 2,240 lb. per square inch, $t = \frac{3 \times 2{,}240 \times 8}{112{,}000 \times 2} = \cdot 24$ inch. This would be suitable for the semi-positive and flash types of moulds, but frequently, owing to other circumstances, heavier sections may be required.

When holes have to be moulded right through a section, and it is of small diameter, then it is a considerable aid to accuracy if a cone on the end of the pin fits a dimple in the force as shown in Fig. 213. In the case of a stiff pin a countersink in the end will reduce the direct pressure on the mould and assist in producing a thin flash.

Screw threads may be moulded in most plastic materials, provided that the pitch is not too fine or the diameter too small; a reasonable low limit is the No. 2 British Association thread which is approximately $\frac{3}{16}$ inch in diameter and has nearly 32 threads per inch. No. 4 B.A. thread has been moulded, but it cannot be recommended. The length of a thread should not exceed its diameter. Threads cause the gases to be trapped, and care must therefore be exercised to ensure no accurate face adjoins the threaded portion. The methods adopted for producing the threads will be discussed later, but Fig. 214 shows the usual designs adopted for this work: A for small threads, B for threads of larger size, and C threads in the top of the mould, care being taken to ensure that the lock is removed before ejecting the moulding.

There are three conditions under which moulded threads will produce a fit: (*a*) if a machine-cut metal external thread is used in a moulded thread; (*b*) if a machine-cut metal internal thread is used on a moulded thread; and (*c*) if two moulded threads are used together. Different allowances are necessary in each case to accommodate the shrinkage of the material and the unavoidable inaccuracies of workmanship. These may now be considered.

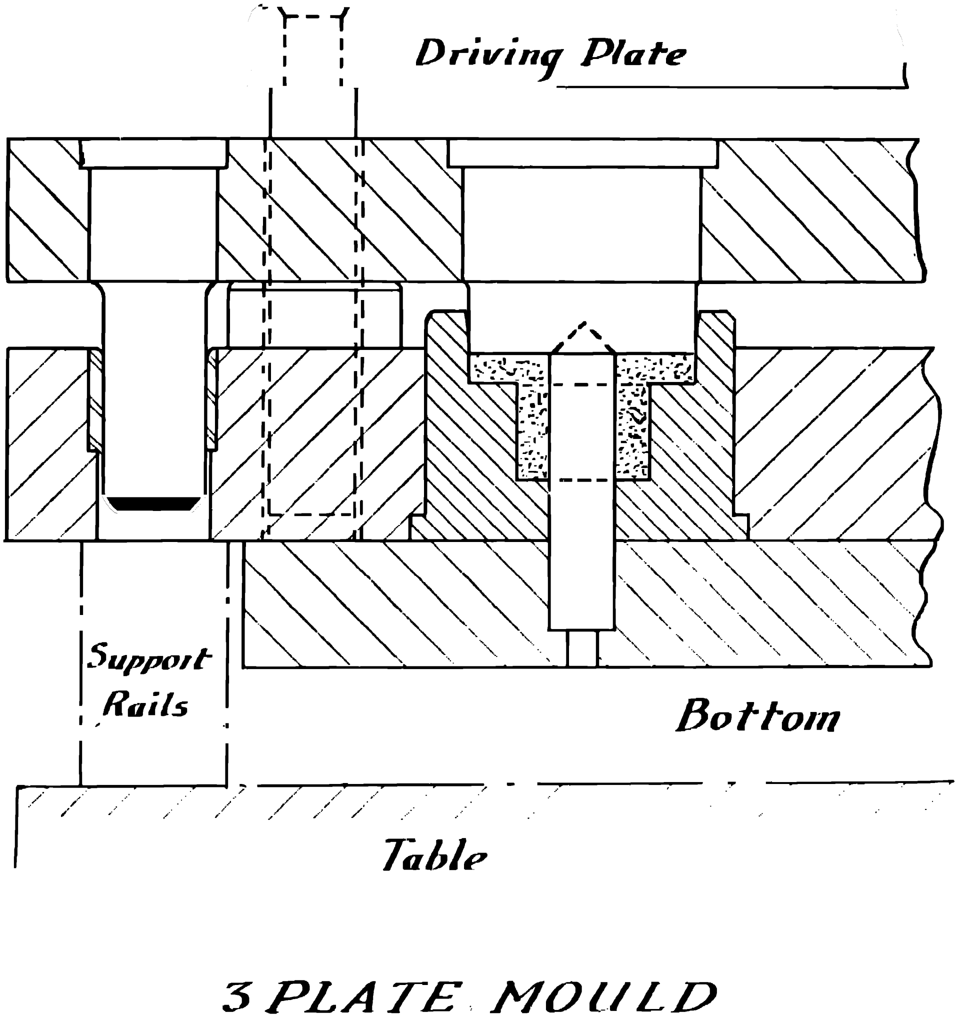


Fig. 213. Centring method of ensuring accuracy of mould locations. (Set up for ejection.)

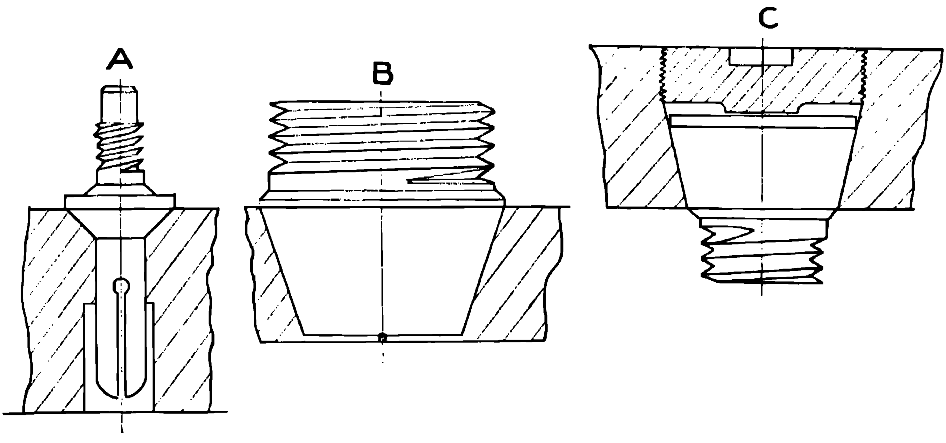


Fig. 214.—Thread-moulding methods.

The vee-shaped threaded bolt will not enter a nut unless the effective diameter is smaller than that of the nut. Now it is not usual for the average tool-room lathe to have a device whereby threads varying only a few thousandths of an inch from standard pitch can be cut; thus as shrinkage takes place on both length and diameter, it is necessary to make the allowances by changing the diameter slightly, thus ensuring that the two pieces will screw together even if the threads are not in contact throughout the entire length. In Fig. 215 the inaccuracy has been exaggerated to illustrate this point, and it will be seen that only the two end threads make contact; as the pitch of a thread is only measured along a line parallel to the axis of the thread, by knowing the angle and the estimated amount of error caused by the shrinkage, the reduced diameter of the bolt may be ascertained. If x is the pitch error measured on the angle of the thread and Y the amount of reduction, it is evident that $Y = x \, Cot \frac{\varphi}{2}$ where φ is the angle of vees; thus in the case of the Whitworth form of thread where $\varphi = 55°$ the value of $Cot \, 27\frac{1}{2}°$ is 1·92, so that $Y = 1{\cdot}92x$; but the almost negligible difference between this value and $2x$ is neglected and thus $Y = 2x$.

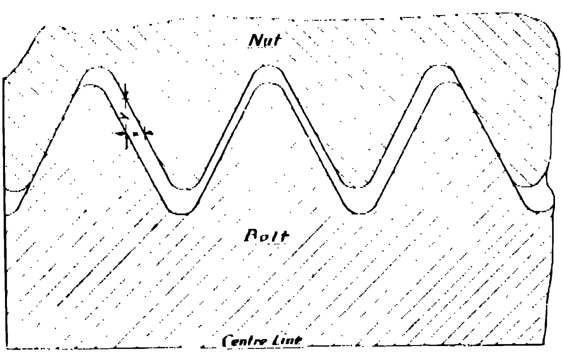


Fig. 215.—Pitch error affecting fit.

Applying this to case (*a*) let L = length of the moulded nut; D = the root diameter of the moulded nut; S = shrinkage of plastic per inch; and B = the diameter of the machine bolt. The shrinkage of L = LS inches; therefore for linear shrinkage the allowance on the nut is 2LS, but the shrinkage on the diameter = SB inches. Therefore the total shrinkage = 2LS + BS = S (2L + B). Now, if C is a constant to take care of the inaccuracies, the root diameter of the nut D = B + S (2L + B) + C.

In the case of the metal nut, if B = the root diameter of the nut; D = the outside diameter of the moulded thread; L = the length of the nut; S = shrinkage per inch; and C = the constant for inaccuracies, then the allowance for linear shrinkage is 2(LS) to be subtracted. The diametrical shrinkage from the nominal is B × S, but this has to be added to the diameter. Therefore the total allowance is equal to − 2LS + BS, which equals S (B − 2L) and the diameter D = B − S (B − 2L) − C. When the threads are both moulded only the diametrical shrinkage plus the constant is allowed.

Inserts.—Inserts are to be commended, as they may be made of almost any material providing it will stand the moulding pressure and temperature. They permit the use of simpler moulds and assemblies, and small

internal threads may be accommodated by means of an insert. Consideration must, however, be paid to the position of the insert. This should be in the vertical position or parallel to the moulding line and should be held rigidly by the pin or recess provided for location, this implying a fairly accurate production of the piece. Horizontal inserts are difficult to deal with and must be short, as they often have to be kept in place by a nut or bolt from the outside of the mould. Long pins should be supported at each end, otherwise they are liable to be sheared off during the moulding process. For screws or nuts, round sections, knurled to a diamond shape, of fairly coarse pitch are the best, as if

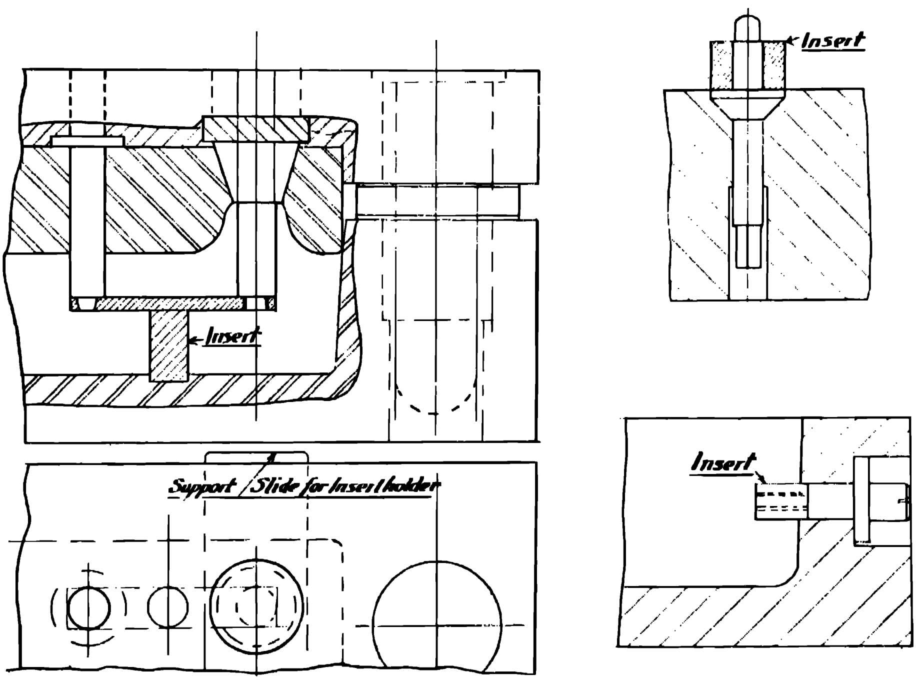


Fig. 216.—Methods of holding inserts.

hexagon bar is used, it is necessary to turn a shoulder to provide a suitable location, and in any case a groove is required to prevent it being pulled out. In the case of large inserts, arrangements should be made for plenty of material around the piece, otherwise cracking will occur, due to the difference in the coefficient of thermal expansion. It is sometimes arranged for the inserts to be put in moulded cavities immediately after ejection so that the moulding upon cooling will grip the piece. This is common for small inserts in very big work or for light inlays. Fig. 216 shows three methods of holding inserts.

As mentioned previously, all types of moulds, except the positive, need guides or locating pins to ensure correct alignment between the top and bottom parts of the mould. These should be of robust section, and

be a good sliding fit into the hardened bush. There is very little to choose between the pin at the top or at the bottom, although if the pin is at the bottom it may interfere with the operator. The pin shown at A in Fig. 217 represents an incorrect design, for it is not easy to bore both the holes in line, due to the different diameters, except on a special borer; moreover, if bent by accident when in operation, this type of pin would cause damage to the hole on being driven out. The pin shown at B, however, is easily removed, and needs only one hole of accurate dimension. As there is the possibility of the two parts of a mould becoming separated, it is important that the pins should be arranged so that it is impossible to reverse the parts. In the case of circular tools this is arranged by making the pins unequally spaced, while in the case of two or four pins in a rectangular mould, one pin of different diameter is effective. The pins and bushes are pressed in, and the allowance in inches may be calculated from the formula: allowance = $\cdot 001 \times D + \cdot 0005$, where D is the diameter of the pin in inches. The pin is shown at the bottom at C, with a pad bush in the plate.

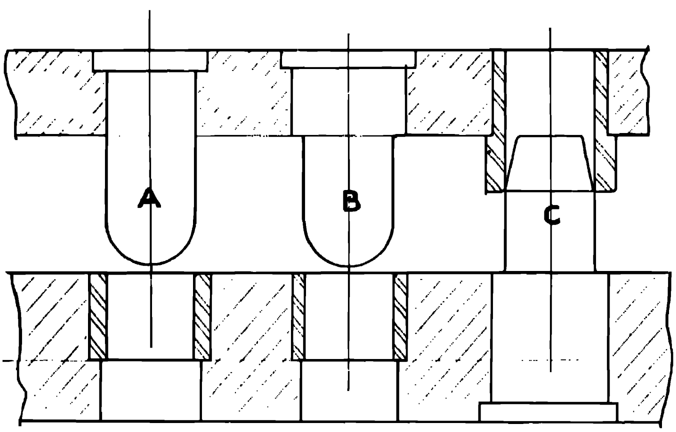


Fig. 217. Aligning pins.

It must be understood that in the case of large moulds, the pins may be as much as 30 inches apart, and thus seizing troubles may occur, due to the unequal thermal expansion of the mould. In such cases a little more clearance than the usual may be permitted, but the amount is only obtained by trial and error, and great care must be exercised, otherwise uneven mouldings will result.

Hand moulds may be chosen (*a*) because the moulding is intricate and considerable time in setting up of loose pieces is necessary; (*b*) insufficient numbers are required to justify the cost of an automatic mould; and (*c*) the press capacity available demands the use of this type. Hand moulds should be as light as possible, commensurate with strength, handles must be provided, and, if over 50 lb. in weight, slides or runners from the press to the ejection bench should be provided. A series of standard heights assist the operation of two or more moulds. In the case where there are a number of mouldings of different design, but each of about the same weight and size, it is possible to make a standard bolster with holes bored to take a number of forces; thus, it may mean

that in a twenty-four-impression mould, twenty-four different articles would be produced in the same material, as shown in Fig. 218. Injection moulds are used when the plastic is cellulose-acetate compound, which is a thermoplastic with little filler, to be produced on the special injection-type machines.

Ejecting the Mould.—Ejection methods may be divided into two main groups: (*a*) hand, and (*b*) automatic, there being several fundamental principles governing the arrangements adopted. Ejection must take place without distortion; this means that the pads and pins should contact

Fig. 218.—Multiple moulds for valve holders. (A. Herbert, Ltd.)

against the solid sections, and if more than one is used they must contact simultaneously. Further, curing plates or simple fixtures must be provided when necessary to hold the moulding at the important points, so that, whilst cooling, any movement taking place does not affect the accuracy of the part. In the case of flat mouldings it is necessary to clamp them in a light press to prevent twisting. Plastic compounds shrink upon cooling, the movement being away from the cavities and towards the pins, and this can sometimes be used in such a manner that no actual ejector is necessary beyond a blast of air. In cases of doubt as to the correct procedure, it is advisable to provide discharging means from

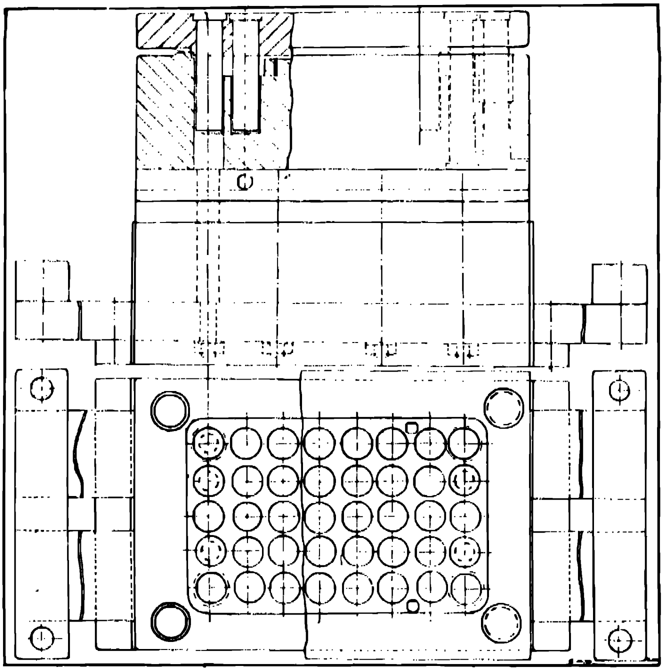


Fig. 219.—Mould of multiple style showing ejector frame.

both forces. On no account should a steel hammer be used, but a fibre or raw-hide mallet is permissible. The arbor press is useful in pushing forces from positive moulds.

The most simple method of parting a flash or semi-flash mould is to cut two steps in the bottom part, and with two levers and an adjustable levering frame prise the top off (Fig. 220). If the piece is liable to stick, but is of simple design, a large-headed "knock-out" pad should be incorporated, care being taken not to mark the article. It should be noted that the pad is set $\frac{1}{8}$ inch into the force, as this prevents the powder lifting it upwards during the squeezing period. A piece of soft metal is sometimes screwed into the pad and used for driving purposes.

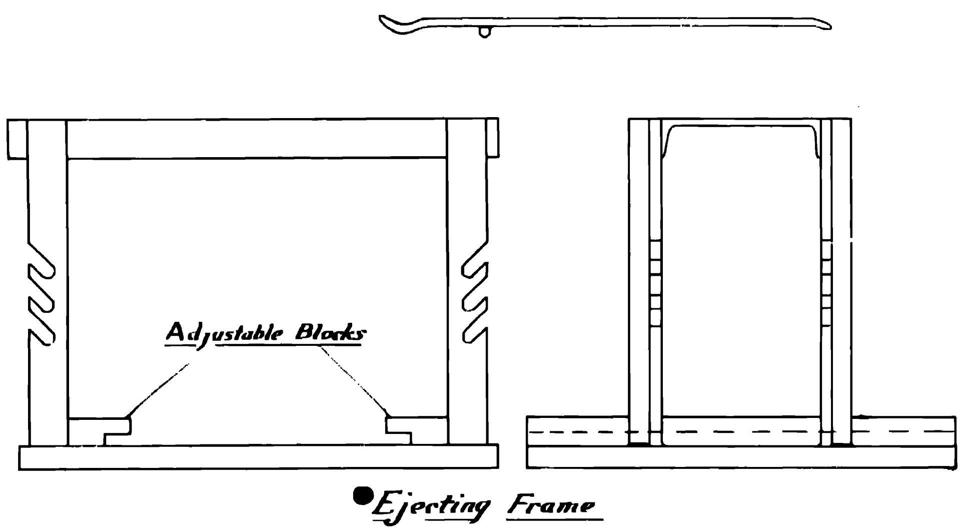


Fig. 220. Levering frame for parting a mould.

Long tubular pieces may be conveniently ejected by cutting a single thread on the plug member of the mould, a twist sufficing to ensure easy removal, particularly if a small taper of not less than ·002 per inch be allowed.

When loose moulding pins have to be withdrawn, fixtures to hold the parts are attached to the jaws of a quick-acting machine vice and the vice opened. This is very useful if the pins are long.

Automatic Ejection.—There are four methods employed in order to obtain automatic ejection of the mould, *i.e.* by the use of: (*a*) a stripper plate, (*b*) a spring-loaded frame, (*c*) tie-bars, and (*d*) an auxiliary hydraulic ram. The stripper plate may be used on single or multiple moulds which comprise a bottom cavity force and an upper force, and consists of the plungers together with a plate that slides on the plungers. This plate is retained by shoulder bolts screwed into the top platen, but is kept flush with the bottom of the plungers by springs when in the open position. When the platen descends the plate contacts with the bottom forces whilst the plungers continue downward to complete the stroke, at which point the shoulders touch the stripper plate. In this way semi-positive action takes place. The primary function of the plate is to facilitate the ejection of moulds such as thin-walled cups, etc., as it would be possible to push a hole through the bottom if an ejector is used, or to damage the top edge if it is held on the plunger. This type may be used for pulling off bottle caps, etc., even though they have an internal knuckle thread. The plate, of course, must be rigid enough to withstand appreciable bending.

The spring-loaded ejector is usually employed in connection with down-stroke presses, and consists of four adjustable stops attached to the head of the press. Attached to the ejector bars are bolts which pass upwards through the moving platen with springs between the upper ends of the bolts and the top of the platen. Its action is simple, since on the return stroke, when the heads of the bolts strike the top stops, the ejector pins force out the moulding, the springs drawing the pins into the force on the down stroke. One great advantage of this method is that it leaves the working space quite clear.

The tie-bar is sometimes used in connection with the above method, but it may also operate independently. From the ejector bars adjustable tie-rods pass through the opposite platen, where nuts are screwed on until the ejector pins are free of the forces, the nuts afterwards being locked. The top platen is then dropped slightly in order to sink the pins, and after the mould is opened the rods pick up the final part of the stroke and pull up the bars and pins. One disadvantage of this method is that the pins protrude whilst the mould is open unless special provision is made to force them down.

The hydraulic ejecting device consists of a detachable hydraulic cylinder with a spider-like fitting at the end of the ram, this being placed under the bottom platen and operated either by an interlocking valve

or an independent valve. This device may be fitted on the table for the removal of horizontal pins when necessary.

When making moulds for plastics no hard-and-fast rules of procedure are possible, as the design varies so much that each mould represents a separate problem. Inevitably, however, the question of built-up versus solid moulds sooner or later arises. There can be no doubt but that the former method affords considerable saving of costly materials as well as much machining, but there are many attendant drawbacks, the chief of which is that after a short time slight ridges are formed, due to the moulding powder forcing its way into the joints and thus spoiling the smoothness of the mould surfaces. Should built-up construction be decided upon, the joints should be parallel with the moulding line, as perpendicular jointing frequently causes a jambed moulding, the powder acting as an anchor in the joints owing to the fact that these are at right angles to the line of ejection. Wherever possible built-up moulds should be surrounded by a shrunken ring or sleeve which, keeping the parts tightly together, will prevent, to some extent, the powder-creep, although it has been known to creep between the faces, even when the moulds are so constructed. Hence, on the whole, it may be said that solid moulds produce better mouldings even if first costs are higher.

Production of Moulds.—The methods of producing moulds may be divided into three classes: (*a*) using only standard tools and machines, (*b*) using machines which have been developed to do a number of operations with one setting of the work, and (*c*) using the special tools and machines which have been designed chiefly to satisfy the demand of the rapidly developing plastic industry for cheaper moulds.

Assuming that the piece of steel for a single impression mould is machined ready for marking off, it is first coloured to enable the mould-maker to see the very fine lines drawn on the surface of the marking-off table, which will show him the outline for machining. The colouring of the steel may be done either by placing it in a tempering bath until it has reached a bright blue shade or by applying a solution of the following composition: selenious acid 20 grams, copper sulphate 10 grams, water 80 c.c., and a trace of concentrated nitric acid. After application the block should be washed in water and dried. If the force is circular, and the impression also circular, then it would be turned on the lathe, using a template gauge to ensure correct contour. The block is then placed on a surface plate, and the centre line marked off, using a vernier height gauge reading in one-thousandths of an inch, the rest of the lines being then marked off according to the drawing dimensions. The drawings should be dimensioned, using rectangular rather than polar co-ordinates, which for this work are not so accurate and tend to cause confusion. The holes necessary are bored to the depth required, and the rest of the material removed either by end milling or slotting. A modern end-milling machine with swivel head is shown in Fig. 221. The impression is then finished by hand tools and polished.

The production of the moulds is highly skilled work, and accuracy depends not only upon the ability of the mould-maker to scribe the line in the proper place, but also to cut along the centre of the line, which may be only $\frac{2}{1000}$ inch wide, and finally to obtain the high polish needed. In the absence of special boring machines, which enable holes to be bored with great accuracy of dimension and position without marking off, there are two alternative methods used by the mould-maker to obtain accuracy, these being similar to those already described in the chapter dealing with the production of sheet-metal press dies. The first is by scribing on either side of the centre lines at a distance equal to the radius of the hole to be bored, thus producing a square. The holes are then drilled and bored, the mould-maker watching carefully to see that the lines are in the correct place relatively to the hole. It may be observed that the indication of error is really twice that of the actual error, since it appears on both sides of the hole. The second method is by setting what are known as "tool-makers' buttons" in the exact place where the holes are to be bored. This is done by means of precision blocks or by the use of the vernier height gauge, and after setting up the block in a lathe so that each button runs true as indicated by a dial indicator, the button is then removed and the hole is bored. The position of the holes is first obtained and holes drilled and tapped to suit the button screws, these being tightened when the button is in the correct position.

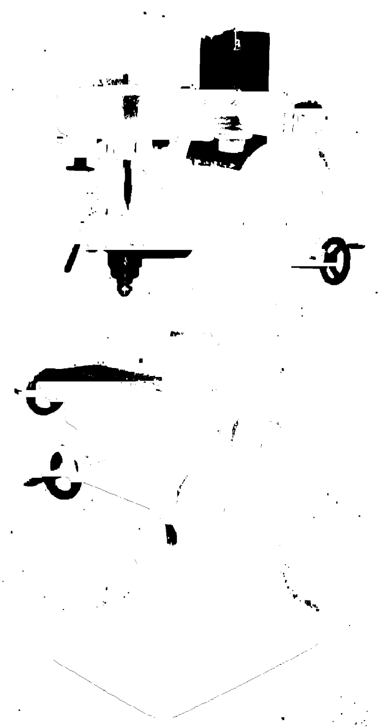


Fig. 221.—C.V.A. vertical milling machine. (E. H. Jones M/C., Ltd.)

In the case of multiple-impression moulds the bolster plates are usually surface ground, clamped together, marked off, and bored to suit the mould forces, which are made in a manner similar to that described above. The depth of the impressions must be accurately controlled, otherwise some forces will not meet and the powder will flow out, leaving a spongy product. Split moulds require very skilful manipulation, as the joint face must come exactly on the centre line. If one half of the mould block is left slightly big the step formed can be used for setting-up purposes.

In order to reduce polishing costs, a small electric motor with a flexible shaft is used, a chuck being attached to the free end of the shaft, which will take the small abrasive polishing wheels and the various shapes of bobs. As most of the steels used in the production of the moulds are

hard, machining should be carried out by using either tungsten carbide or 22% tungsten high-speed steel, and no attempt should be made to machine a piece by using a form tool, as this will inevitably cause the surface to tear—the higher the nickel content the greater the trouble; hence forming the mould must be done with a fine-pointed tool used in conjunction with a profile gauge.

Threads are best cut on a thread-milling machine; but if such a machine is not available then they may be cut in the lathe, providing great care is taken to pull out the cross slide before the split nut is opened, otherwise the slightest mark will prevent the moulding member from being removed from the mould. The tools should be precision ground and lapped,

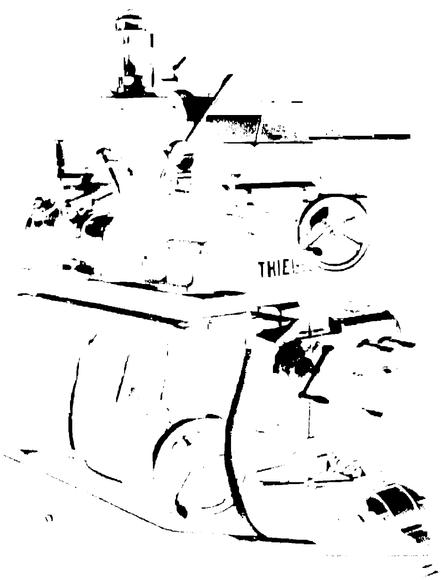


Fig. 222.—Universal tool-room milling machine. (E. H. Jones M/C., Ltd.)

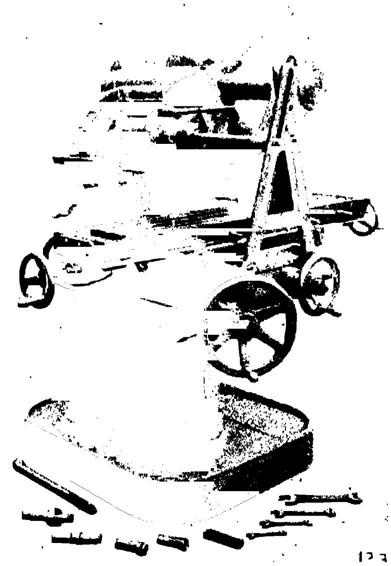


Fig. 223.—Adapta milling machine. (J. Parkinson & Son.)

as only the absolute minimum of hand polishing may be allowed. The end of the thread should be removed so that there is no feather edge, which may be easily damaged when in operation. No attempt should be made to cut the thread right up to a shoulder.

Production assisted by special machines possessing various devices and adjustments is becoming very popular because of its wide application and general utility, such machines being available for use in the making of other work such as press tools. A particularly interesting machine of this type, shown in Fig. 222, is the Theil 58 Universal tool-room milling machine. It is designed for all types of milling, drilling, reaming, boring,

and slotting, and may also be used as a copying machine. All these operations produce work to very close limits and without the removal of the job from its first setting. Power feeds are available in three directions, and provision is made to set each slide, using vernier scales incorporated in the main slides or by using precision slips and a dial indicator in any given position to extremely fine limits; thus it may be used as a "jig borer." As a form miller with a profiling attachment, it provides means for sinking the cavity of a mould from a model. It may also be set up for the complete machining of master hobs. Another machine of this type is the Adapta milling machine, shown in Fig. 223, the process of end-milling a mould on this machine being shown in Fig. 224.

Fig. 224. The miller cutting a mould.

The development of special machines for die sinking was a natural outcome of the laborious and costly hand process of die sinking, but a great many problems had to be overcome in the search for a satisfactory method of producing a machine capable of three-way instantaneous adjustment. The first type developed was the pantographic machine developed from the engraving machine. A machine of this type is shown in Figs. 225 and 226, and, as will be seen, a model in wood, plaster of paris, or bakelite can be set up at a definite distance from the pivot, the block of metal forming the mould being placed so that the predetermined ratio of reduction is ensured. Cutting may be controlled either by hand or by automatic feed until the mould is roughed out, after which the free movement of the pantograph is used to cut accurately to the model which guides the tool. It is important that the cutter and guide pin be of the correct size and shape to one another.

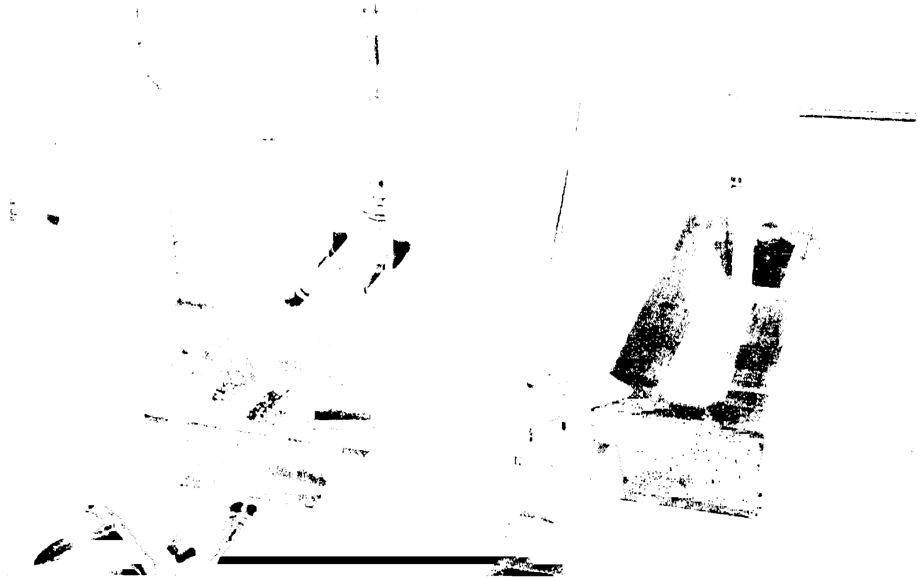


Fig. 225.—Pantographic die-sinking machine. (G. H. Alexander M/C., Ltd.)

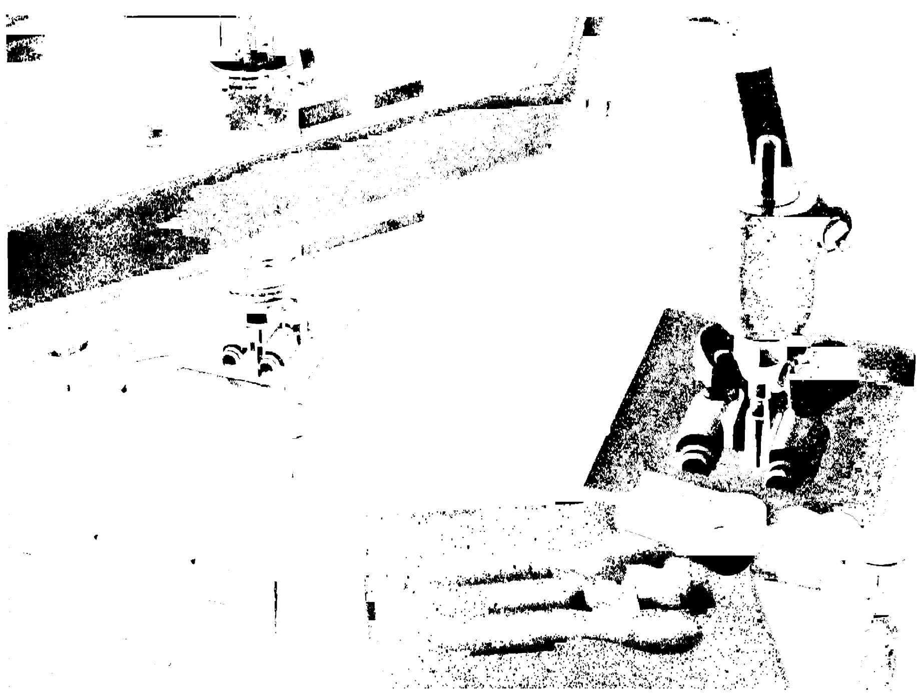


Fig. 226.—Another example of pantographic copying.

Another type of machine uses the automatic copying method without the pantographic principle, this machine being illustrated in Fig. 227, while Plate facing p. 224 shows various moulds produced by it. The machine is electrically operated and controlled throughout, provision being made for manual adjustments and operation when required, but after once setting up, the machine is completely automatic in action. The design is similar to that of a horizontal milling machine set up for end milling, there being one cutter spindle and a tracer finger mounted parallel and above the cutter, but operated on the same slide, so that, if the work is mounted on a special bracket, and the master in the corresponding place

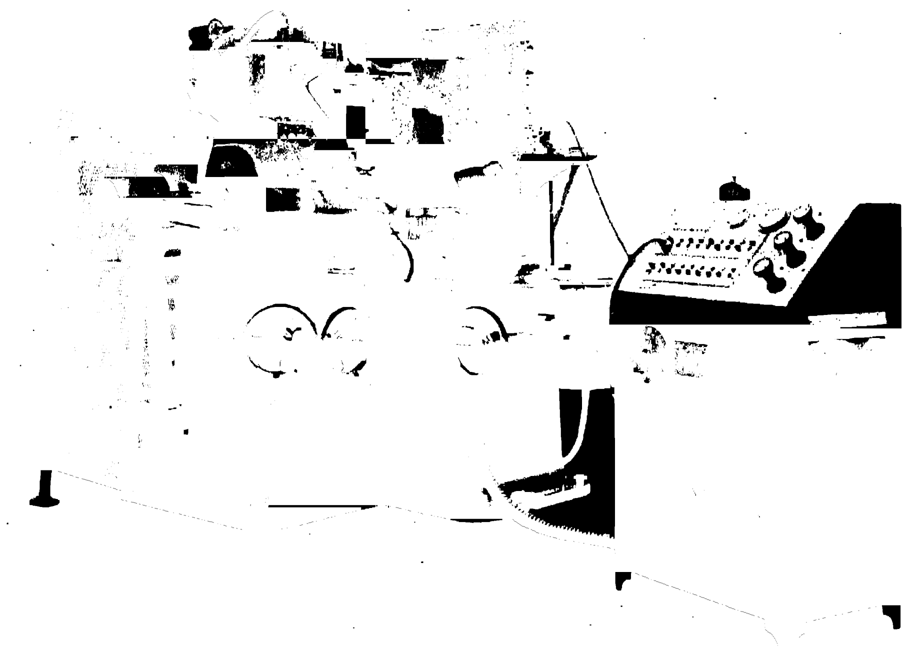


Fig. 227.—Keller die sinker. (A. Herbert, Ltd.)

above, the finger and the cutter being alike, then, by tracing the finger over the profile of the model the cutter will remove the material from the mould block, and an exact replica of the mould is provided. The distance between the finger and the cutter is adjustable to assist in setting up. The feed may be vertical or horizontal, and the electrical control is so sensitive that it permits travel until the slightest pressure on the finger causes it to operate a switch, which stops the travel and causes the tool to feed at right angles into the material. A series of lines is thus made either vertical or horizontal, and the outline corresponds to the model. This is called contour operation and is only suitable for flat-bottom work. The third-dimensional movement is controlled by the

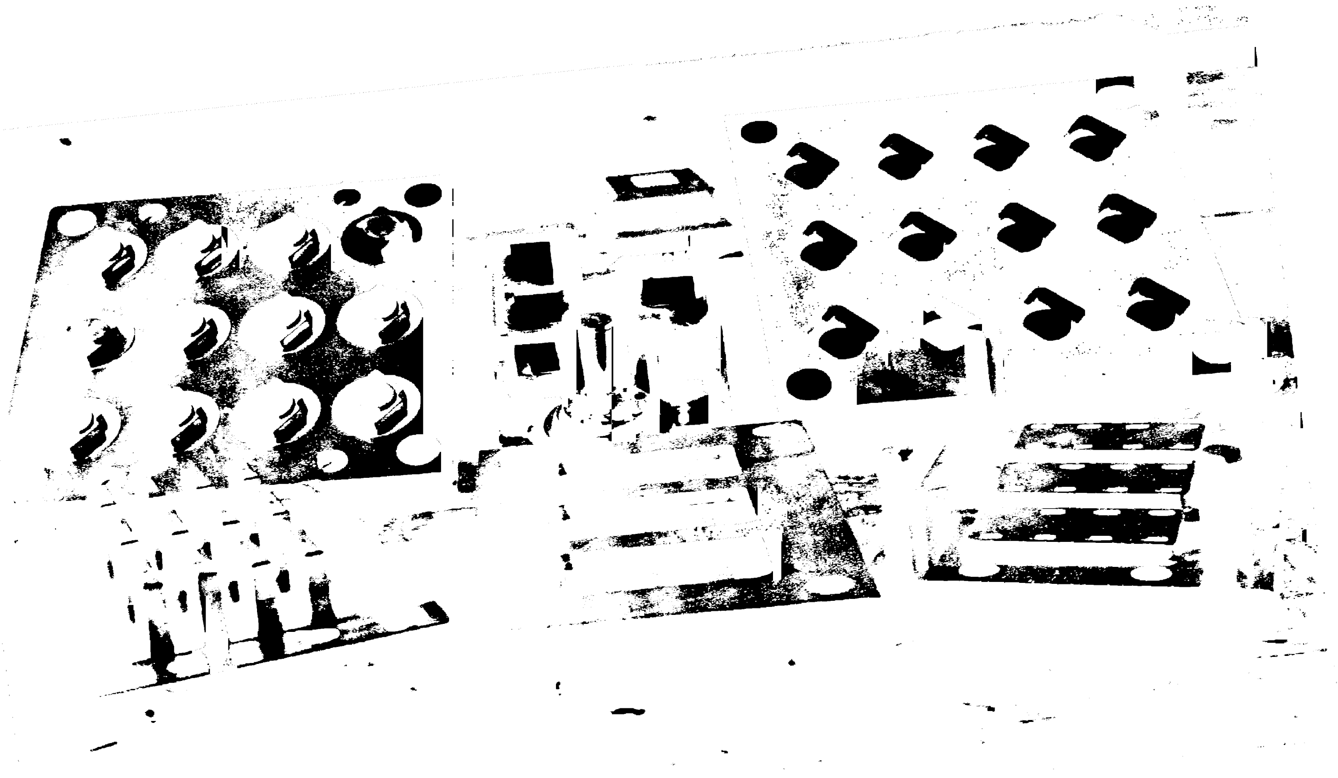
automatic movement of the tracer, which, with the cutter, moves perpendicular to the face of the mould. From the moment contact is established, the varying degrees of pressure on the tracer, as it seeks to contact with the surface of the master, cause the cutter spindle to respond to the in-and-out movement, so that as the cutter travels in the way previously described the additional movement in the third dimension is taking place, an accuracy of ·001 inch being maintained. The electrical circuit is very sensitive, and the most intricate contour may be cut in a remarkably short time. Machines of this description have been built to enable three moulds to be cut simultaneously.

A die-sinking machine of the generating principle which has been recently developed is worthy of note. The copy principle incorporated in previous machines requires a model or master form, but this is not required in the machine under notice. Actually, the machine generates the cavities and plungers from the cross slides, the circular movement of the superimposed rotating table, and an oscillating movement of the cutter spindle. The latter movement is obtained by an ingenious device whereby the spindle not only rotates but may travel laterally through a semicircle either upwards or downwards from the horizontal face of the machine, and the radius is adjustable from zero to 3½ inches. It is evident that such a machine can produce a wide range of shapes and forms from first principles and is of great utility.

Attention may also be drawn to an interesting device which has been incorporated in a particular design of centre lathe, whereby almost any shape, so long as it is balanced around the centroid, may be turned. By using a simple template for guidance, any contour may be cut, and all regular polygons, ellipses, etc., can be produced without trouble, and in the case of polygons the sides may be either straight, concave, or convex.

Fig. 228.—Hobbing press. (T. H. & J. Daniels, Ltd.)

Hobbing is not a new process, as it has been used by workers in precious metals for many years. Its application to the production of moulds is of fairly recent introduction and may be said to be due to three factors: (*a*) the high cost of multiple impressions, (*b*) the difficulty of producing replicas, and (*c*) the limitation of design due to machining difficulties. The operation consists of forcing a master hob, which is an exact replica of the moulding made from a special dense and tough steel, into a prepared blank of soft steel. The whole process is carried out cold on a specially designed press (Fig. 228) capable of withstanding the enormous pressure of between 100 and 200 tons per square inch. The



EXAMPLES CUT ON THE KELLER MACHINE.

face of the blank is highly polished, otherwise any blemish is carried to the bottom of the impression and, of course, the master hob is also polished after having been carefully hardened and tempered according to the steel-makers' instructions. Too much attention cannot be paid to this heat treatment, as it must stand up to the great pressure mentioned above without the slightest deformation, and, at the same time, without breaking, for obviously serious consequences might result if the hob were to break under such pressure. Once the hob has started it must not be stopped, otherwise a slight ridge occurs at the point of stoppage, and this is difficult to remove. It is necessary to use a shroud or retaining ring, to support the blank and guide the hob; this is made of 60-ton alloy steel, but untreated after being machined (Fig. 229), otherwise, due to the lateral pressure, cracking may occur along the walls of the impression. Soft case-hardening steel is used, although research work may perhaps in the near future produce a really successful direct-hardening steel which will avoid this unfortunate limitation to a most useful process.

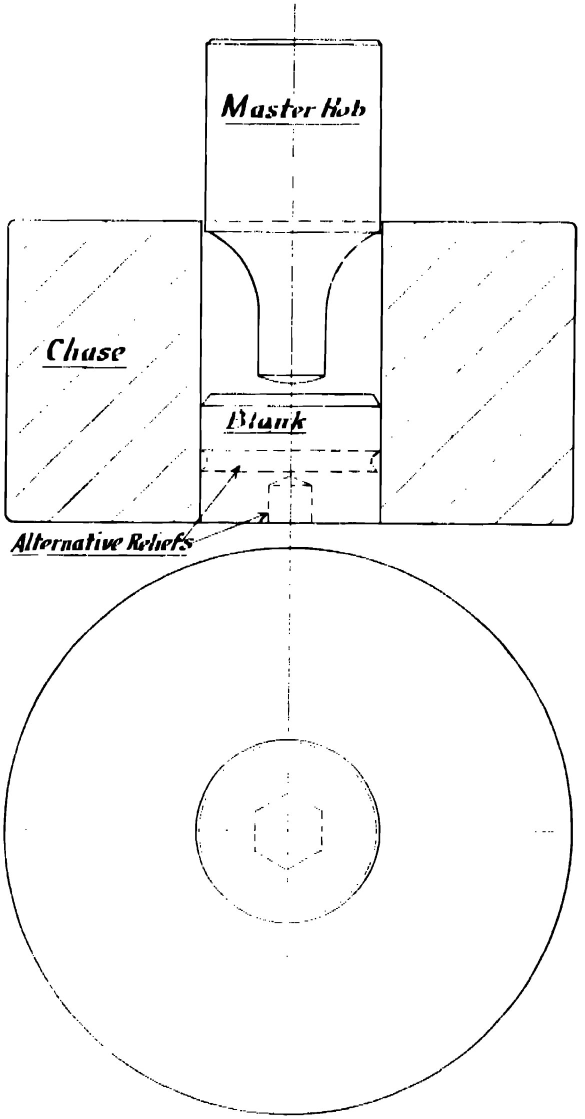


Fig. 229.—Hobbing tools.

Following the hobbing and subsequent machining, the material has to be case-hardened. Much can be done to relieve the pressure by the

removal of material from the blank, the usual way being to drill a hole in the bottom, but this must not be as big as the impression, or the plug of metal will be pushed through. As a result of investigation, it has been proved that relief around the sides at a depth where the hob face reaches is more effective than the bottom hole and less distortion takes place during the heat treatment; but on no account must the top face be touched. The size of the blank relative to the impression should be not less than twice the average diameter of the hob and not less than twice the depth, as this allows for subsequent machining. When polishing the master hob, it must be done in line with the direction of push, or trouble may arise through the blank surface adhering to the hob, due to the high coefficient of friction between the two surfaces. Although it is possible to hob an impression so that sunken letters appear on the mould, it is not to be recommended owing to the enormous pressure required when hobbing.

Plating.—All moulds except stainless steel should be chromium-plated to ensure the best results. Chromium has a low coefficient of friction, it is very hard, and being chemically inert it will not stain. Only a thin coating is necessary, from ·0005 inch to ·001 inch being ample. If the layer is too thick it tends to crack off, due to its hardness and the difference in the coefficient of linear expansion between it and the steel of the mould. On no account must surface blemishes be left, as they cannot be concealed by the plating.

Glossary of Terms used in Moulding Procedure.—*Curing Period.*—The time taken for the chemical reaction to be completed, and is considered as the time the mould is actually closed. This term is also used when moulding thermoplastics, although actually no chemical reaction takes place.

Cycle.—The time taken for the production of a moulding or mouldings by a single mould; it includes the time for curing as well as the time for handling.

Breathing.—The opening of the mould for a few seconds to allow the gases to escape.

Blistering.—The uneven appearance of the surface due to various causes, such as having the mould too hot, closing the mould too quickly, or using unsatisfactory moulding material.

Burning.—Bleaching of the surface or blistering caused by using too high a temperature or keeping the material too long in the mould.

Dwell.—The holding of the press at about $\frac{1}{8}$ inch from the closed position for 5 to 10 seconds before closing to eliminate danger of matt spots or "air marks" in the moulding, a blemish due to the humidity of the air.

Flow.—In the manufacture of the powder the nearer it is to the completion of the chemical reaction when sent for moulding the stiffer the flow. When it has not been taken so far, it is called free flow, and in this state requires a slightly longer curing time.

Flow Lines.—Indications in the moulding of how the powder flowed

during the squeezing, a fault caused by slow closing or too low a temperature. The use of pellets may also be the cause.

Pre-heating.—The heating of the powder at 80° to 100° C. in an oven before moulding in order to speed up production and to avoid blisters. The actual time required for pre-heating is decided upon by the curing time—the material must not be kept too long at this temperature or it will pre-cure.

Under-curing.—This can only be confirmed after ten minutes' boiling in water, when, if the mould is under-cured, a whitish bloom will appear and the material will become soft.

Matt Spots.—Spots due to damp powder or pre-curing.

Moulding Technique.—When the new mould is first received by the moulder for a thermo-setting plastic, it is not ready for service, but has to be " run in." It is first of all cleaned to remove the protective grease and then heated to moulding temperature. The first charge is weighed out a little heavy, and if no sample is available a volumetric calculation allowing ·8 oz. per cubic inch is sufficient. The mould is then smeared with olive oil or paraffin wax, the powder is charged, the press having been set to the estimated pressure required. The press is then closed for the estimated curing time based on the powder-maker's recommendation, this being usually 25 seconds per millimetre for phenol powders and 40 seconds per millimetre for urea powders. The first mould should jump out, and after four to six cycles the mould should be in good working order, the face then having the inertness needed to produce smooth mouldings without sticking. However much the surface of the mould is polished it is always necessary to carry this process through, although chromium-plated moulds do not need so much preliminary attention.

There are only slight differences between the moulding technique of phenol powder and urea powder, but they must be carefully observed to ensure really good mouldings. There are several kinds of powder used in both classes, those in the urea classes being known by the trade names of Beetle, Pollopas, Scarab, and others. Each has its particular advantage, but they are not all recommended for conditions where they are subjected to dry heat or are in contact with battery acid, etc., neither is it recommended that heavy inserts be incorporated in the moulding. Pollopas is used where compositions having a high moisture content are to be contained in the urea mouldings, while Scarab is very useful for electrical fittings. Mouldings from these powders can, with the exception of Scarab, be produced either translucent or semi-translucent or opaque. A transparent powder is now made in Beetle, and this must not be moulded at a greater temperature than 275° F. Urea powders are quick-curing and need a very accurate temperature control, plus or minus 4° F., as well as a rather greater intensity of pressure than phenol powders. Pre-heating may be carried out, but non-metallic containers must be used. The design and accuracy of the mould are very important, due to the danger of porous mouldings being produced if the powder is allowed

to flow too quickly through the escape channels, and for that reason no auxiliary grooves are permitted. Figs. 230 and 231 show examples of plastic products made from urea powders. Compressed air at 30 lb. per square inch should be available for blowing the flash out of the cavity before charging, and in some cases it may be used to cool the moulding sufficiently to dispense with an ejector.

Fig. 230.—Beetle mouldings.

Phenol formaldehyde powders are known by the trade names of Bakelite, Nestorite, and Mouldrite Phenolic Type, etc.; they have not the range of colour possessed by the ureas, being limited to the darker shades, but they have a wide range of fillers, and hence they are used in many varied spheres. The temperature control may be a little less critical, about 10° F. plus or minus, but the moulding sequence is the same, *viz.* cleaning, charging, pressing, gassing, curing, cooling (if necessary), and ejecting. The conditioning of the moulds for thermoplastics is not so important, although this does not mean that the moulding may be done carelessly. Due to the fact that no chemical change occurs, the surface as polished is satisfactory. The scrap material may be re-used unless it has been contaminated with foreign matter, as no chemical reaction takes place. Also, as noted above, no curing time is needed.

The moulding of the cold-moulded compounds, which usually consist of fibrous filling materials bound together by oil-varnish residue, is carried out in crank presses. The finish is rough, but the output is good, as the sequence is just filling, squeezing, and ejecting. The mouldings are then baked at about 200° to 400° F. for a number of hours. The production is largely carried out by firms specialising in this type of work.

Casein (trade names Erinoid, Galalith, etc.) is not moulded in the accepted sense, but if heated in boiling water it may be bent and formed in tools similar to the bending and forming tools used in the sheet-metal press shop.

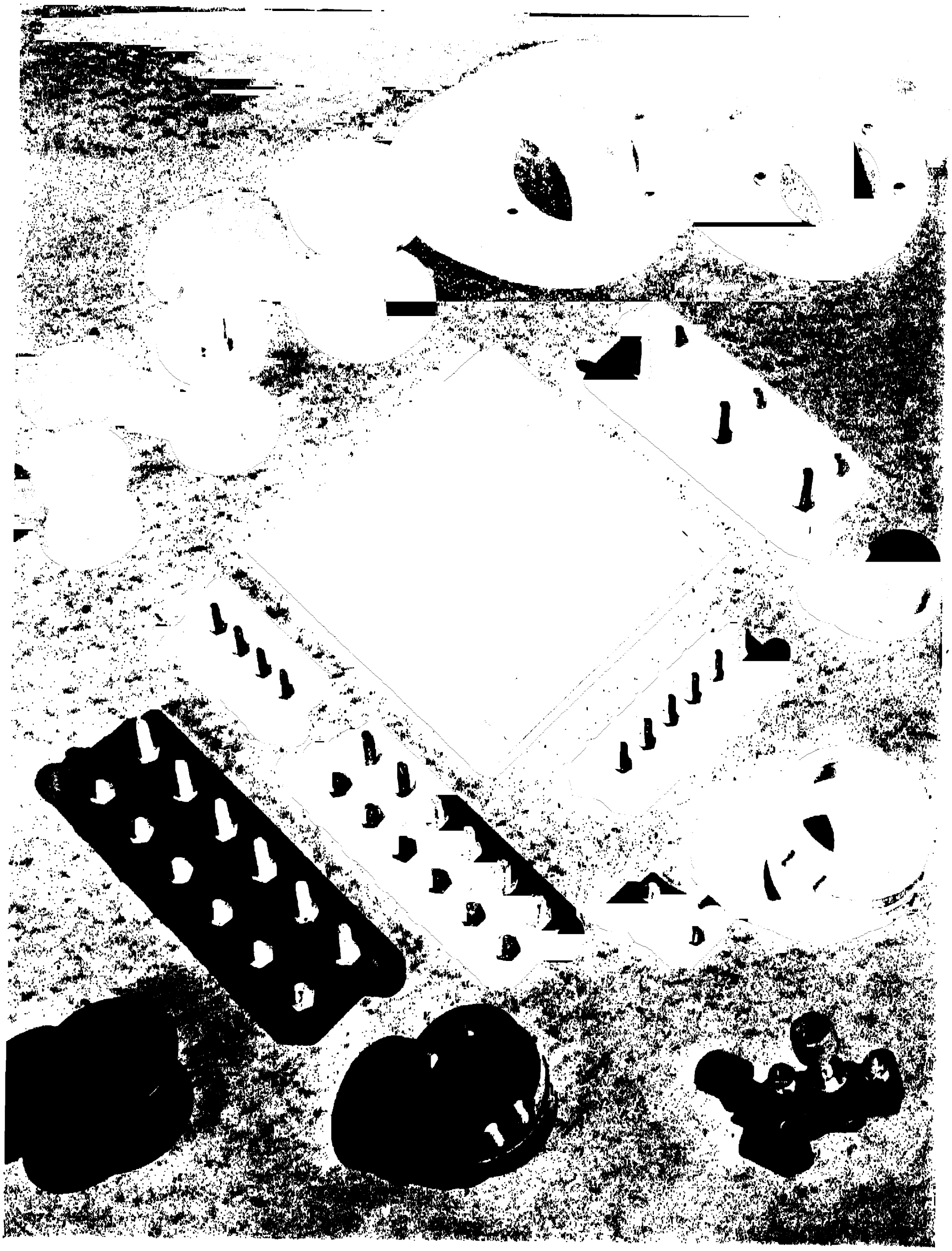


Fig. 231.—Motor mouldings. (Beetle Products, Ltd.)

Finishing Operations.—Finishing operations on the mouldings consist of: (*a*) removing the flash and knife edges, and (*b*) polishing the surface to improve the natural gloss of the mouldings. Regarding the removal of the flash, it is very difficult to obtain a reasonable tool life if ordinary steel tools are used, so that wherever possible emery or carborundum disks and endless belts should be used. The plastic material, however, tends to clog the surface, and only a comparatively short life may be expected. For circular work the most effective method is to revolve the component by power and to rub a file on the sharp edge. Where it is not possible to use the disk or band, the best type of cutter is a hacksaw blade with its teeth ground off, held in a split handle and projecting $\frac{1}{4}$ inch ; being glass hard it lasts a long time and is cheap. From the above remarks it may be realised that a thick flash is a serious cause of reduced production, and it should be the aim of the moulder to keep the flash less than ·004 inch.

Polishing is carried out on thermo-setting plastics, but thermoplastics tend to soften if allowed to get too hot. Ordinary linen mops are used, with a special grade of white wax to assist the polish.

Laminated Material.—Hitherto no mention has been made of laminated material, as its production is usually carried out by firms specially equipped for the work, but owing to the ever-enlarging field of utility to which it is being applied a brief description will not be out of place. The laminated material may be made either from sheets of paper, cotton, linen, or asbestos impregnated with phenol-formaldehyde synthetic resin, these being pressed in multiple platen presses and subjected to heat and pressure in the same way as for normal moulding. The result is an infusible and insoluble product of good mechanical strength, of good electrical insulating properties, and low moisture absorption. The material is usually supplied in the form of sheet, rod, or tube, but simple shapes are also moulded. Gear blanks are always sawn from sheet, the thickness ranging from $\frac{1}{64}$ inch to 4 inches, the size of the sheets being about 42 × 84 inches. One of the most interesting applications of this material is that of making gears, these being strong enough to transmit up to 300 h.p. This laminated material has almost become the standard for gears where a non-metallic material is called for, as there is no need for supporting plates, the teeth being cut across the layers of fabric. The latest application is that of using bakelite laminated material as a bearing material in rolling mills, and even under these arduous conditions where pressures up to 4,000 lb. per square inch are met with, a saving of power ranging from 40% to 60% has resulted, the life of the bearing being six to eight times that of the older metallic-type bearing. The lubricant is water and soluble oil.

There are two methods of design used in the construction of these bearings, one is to space strips of the laminated material longitudinally in the bearing and anchor them to the bearing liner, the other being to mould the sheets to the size and shape required, the bearing being used in the usual way except that special provision must be made for lubrication.

Sheets or panels for decorative purposes are produced by impregnating sections of paper cut to the correct size with bakelite resinoid. These are then arranged one on top of another in sandwich fashion and placed between the heated platens of a hydraulic press. An extremely wide range of colour finishes is available, while any type of natural wood grain can be reproduced by a special photographic process. Such decorative laminated sheets are employed in panels for the treatment of walls or in very thin form as veneers for the surfacing of tables and bar tops where their resistance to the effects of heat, alcohol, and fruit juices is of great value. Fig. 232 shows a press for moulding these laminated sheets.

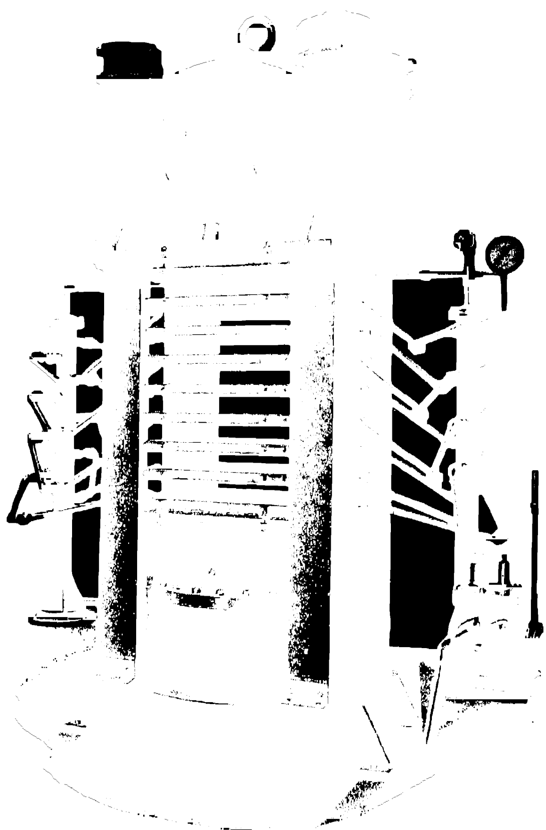


Fig. 232.—Press for laminated sheets. (Francis Shaw & Co., Ltd.)

Machining Plastic Materials.—Machining operations on most thermosetting plastics are to be avoided if this is at all possible, owing to the abrasive action of the material on the cutting tools, although, in the case of thermoplastics, quite a number may be machined and some take a good polish. Casein products are excellent for machining, and they are made into fancy buttons and hand-bag fittings with pleasing effect. High-speed steel may be used, and, providing the tools are kept sharp and the material dry, no serious difficulties occur at speeds approximating those required for machining brass. Tungsten-carbide tools are the best if available, and in the case of drills and taps, specially designed equipment is on the market. It is wise to use a drill slightly larger than is usual for tapping sizes, due to the tendency of the material to close in on the drill.

The machining of bakelite laminated sheet is comparatively easy, and speeds may be used similar to those when cutting brass. The following directions for machining are approved of by the makers :

Band Sawing.—The speed should be 4,500 to 5,000 linear feet per

minute ; the number of teeth not fewer than seven per inch, and these should be of the bevel type sharpened with a set of ·010 inch each side.

Circular Sawing.—An all-metal wood-cutting machine is recommended with a speed of 2,500 to 3,500 r.p.m., the cutting speed varying with the thickness of material. The saw should be No. 11 gauge, hollow ground about ·030 inch small 2 inches from the rim.

Punching.—Press tools of the type generally used for blanking and piercing sheet metal are recommended, but material thicker than $\frac{1}{8}$ inch should not be punched. For greater thickness, a shaving tool is recommended, and the warming of the material in oil or on a hot-plate assists in producing a clean edge.

Turning.—Metal-cutting lathes are used, and the tools should be ground with no top rake and a clearance of 10° to 12°. The cut may vary from $\frac{1}{64}$ to $\frac{1}{8}$ inch, but the feed should remain at ·030 inch, the cutting speeds ranging from 100 to 500 feet per minute. The tools should be set on the centre of the rotation of work, and be kept very sharp. When turning disks, it is necessary to have a backing plate of wood or some laminated material.

Drilling.—The included angle at the point of the drill should be between 50° and 60°, with a slow angle of twist and flutes as wide as possible. Frequent clearing is essential. Should it be necessary to drill parallel to the laminations the included angle of the point should be at least 120°. Care should be taken when breaking through, and, if possible, the material should be reversed for the completion of the hole.

Tapping.—The taps must be kept sharp and wide flutes with narrow land appear to give the best results.

Screw Cutting.—Standard methods may be employed, but the tool should be ground to cut one side only, and advanced for each cut in the same way as when cutting mild steel. Speeds and feeds should also be the same as for screw-cutting mild steel.

Milling.—High-speed steel cutters with keen edges should be used with a fine feed, the cutting speeds varying with the tools and the work. Burrs caused whilst grinding the milling cutter must be honed to prevent a rough finish.

Grinding.—Occasionally grinding is necessary, in which case a wheel of grit not less than thirty-six mesh should be used.

CHAPTER 10

ADVANCED PREPARATION OF SHEETS

THE general principles and geometrical methods of sheet-metal development were dealt with in Vol. I, and the object of this chapter is to explain in greater detail the application in more advanced examples.

In recent years, developments in ventilation and dust-removal plant have caused an increased demand for sheet-metal trunking, and the writer has given special attention to the various types of pipe junctions in use generally. Many examples of conic development are given and different forms of bends dealt with.

For the benefit of the general and construction engineer and draughtsman, various types of hoppers and chutes have been treated with, and the millwright will find the section dealing with conveyor worming of interest.

Aeronautical and automobile work demands a thorough knowledge of the methods of sheet-metal work, and although the machine has displaced the man for certain operations, there is an increasing demand for craftsmen who are capable of developing the large variety of work met with in various sheet-metal industries.

The application of modern gas cutting and welding plant now makes possible the fabrication of steel parts to replace similar articles previously formed of castings or secured by riveting or bolting. The resulting article is stronger, lighter, and more economical, the construction frequently effecting a saving of time, and the finish is often more pleasing to the eye.

In the examples which follow explanations will be given in simple language; and it will be early appreciated that the methods used in development consist of combinations of principles explained in Vol. I.

A small pictorial view of the article dealt with is given in the drawing accompanying each problem, and simple examples will be dealt with first.

Oblique Pipe (Square at Ends), formed in one piece (Fig. 233).—This type of pipe is frequently used to join the ends of square pipes whose extremities are out of line. The elevation of the pipe is illustrated at Fig. X by the figure ABDC. The base and top end are square, as seen in plan (Fig. Y).

To draw the development Z. Normal to BD draw lines through D and A, also C and B.

Parallel to BD at a distance CD^2 draw a line *ca*.

The dimension CC^1 is obtained from the plan and C^1a^1 is drawn parallel to *ca*.

To draw the line *db* make C^1D^2 equal CD^2, and complete the pattern DD^1B^1BD by adding line D^1B^1 parallel to *db*, making dD^1 equal *d*D (Fig. Y).

Oblique Pipe (Square at Ends), formed in one piece (Fig. 234).—This example is similar to that shown at Fig. 233 with the difference that the pipe is turned through an angle of 45 degrees and presented with the corner uppermost in Fig. X. The usual application is that where square pipes are joined when out of line with each other.

Commence by drawing the elevation X and a plan view Y, showing the extremities in their correct relationship.

To draw the development Z indicate lines EA, DB, A^1E^1, and FC parallel to FC (Fig. X), making distances FE, ED, DE^1, and E^1F equal similar distances in Fig. Y, and projecting points D, E, F, and BAC normal to FC to obtain similar points at Fig. Y.

The figure FFCCF represents the one-piece pattern for the pipe.

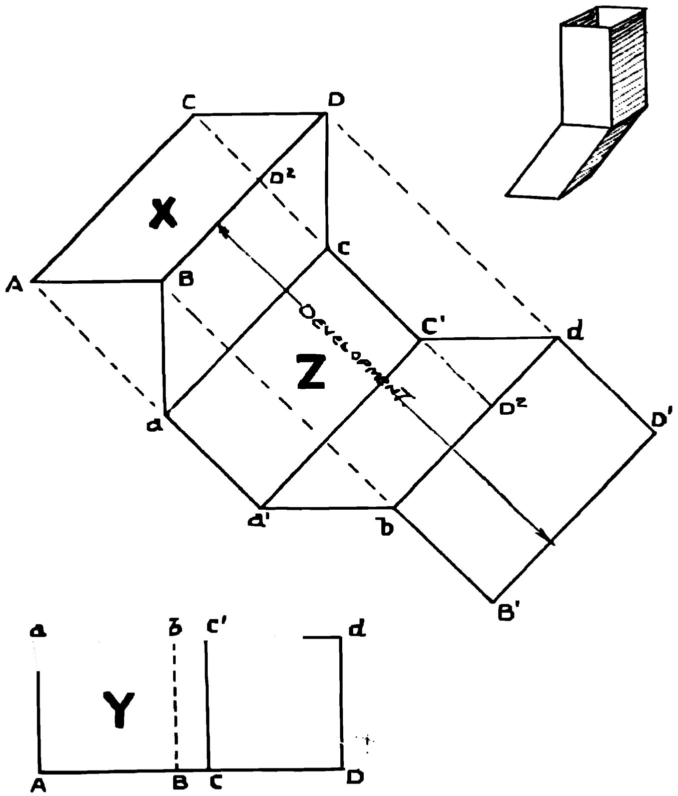


Fig. 233.—Oblique square-section pipe.

Square-section Bend (formed in four pieces) (Fig. 235).—In this case the pattern for the sides is obviously that shown in Fig. W by the area ACDBA. An end elevation is shown at Fig. X.

The pattern for the outside curved surface C*c*, D*d* is a rectangle whose length equals CD and width C*c*. Similarly, the inside curved surface A*a*, B*b* is developed as a rectangular figure of length AB (Fig. W) and width A*a*.

Square Pipe with Oblique Branch (formed in four pieces) (Fig. 235).—This is another example where the elevation shown at Y represents the pattern for the face of the bend.

The top surface D*d*, F*f*, B*b* is a rectangle of length equal to DFB, and width D*d* (see end elevation Z). The pattern for the inner surface C*c*, E*e*, A*a* is also a rectangle of length CEA, and width equal to C*c*.

Square to Rectangular, Right-angle Bend (in four pieces) (Fig. 236).—In the elevation W the figure ABCD does not represent the true shape of the side of the bend owing to the variation in widths C*c* and D*d* (see Fig. X).

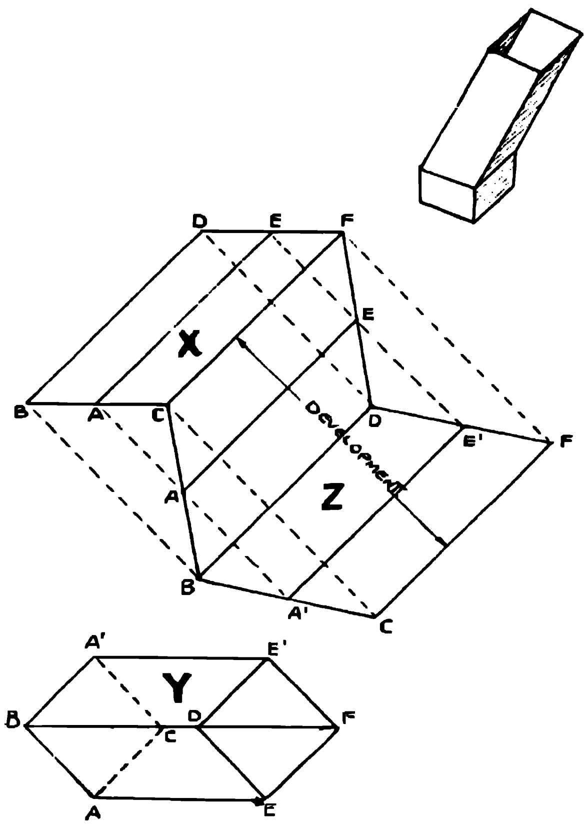


Fig. 234. Oblique pipe (square at ends).

To obtain the patterns for the side, top, and bottom divide CD (Fig. W) into four equal parts, drawing radial lines to O and lettering points HJK and GFE.

Now refer to Fig. X. To draw curves DC, *dc* and AB, *ab* divide the distance aa^1 into four parts and number as shown. Erect perpendicular lines through the numbered points and project points HJ and K horizontally from Fig. W to cut lines 3, 2, and 1 respectively in *h*, *j*, and *k* and draw a curve through these points.

Similarly project points G, F, and E to cut lines 3, 2, and 1 in *g*, *f*, and *e*, and draw a curve through points found. Repeat curves at DC and AB.

Next draw the pattern for the top curved surface C*c*, D*d* (see Fig. Y), drawing lines C*c*, H*h*, J*j*, K*k*, and D*d* parallel, making the distances apart equal CH, HJ, JK, KD respectively (see Fig. W). As the difference in the width of ends is divided equally, the lines CD and *cd* must be straight lines.

The pattern for the bottom curved surface B*b*, A*a* is illustrated at Fig. Z. The overall length in this case is equal to BA (Fig. W) and again the lines BA and *ba* are straight lines.

To obtain the true shape for the side. Normal to FJ and through points C, H, K, and D, also B, G, E, and A draw lines. Now set compasses to JH (Fig. Y), and with J (Fig. W) as centre draw an arc to cut line at H to obtain point H^1. Again with H^1 as centre and HC (Fig. Y)

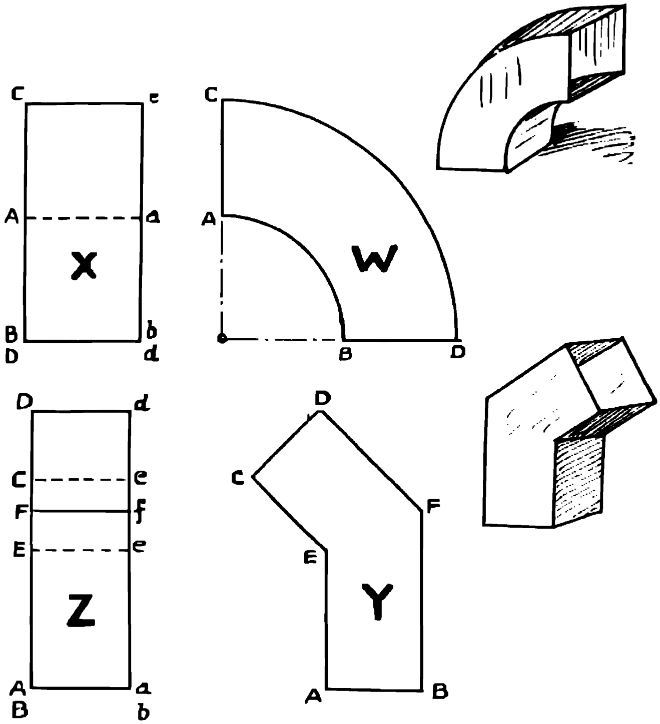


Fig. 235.—Square-section bends.

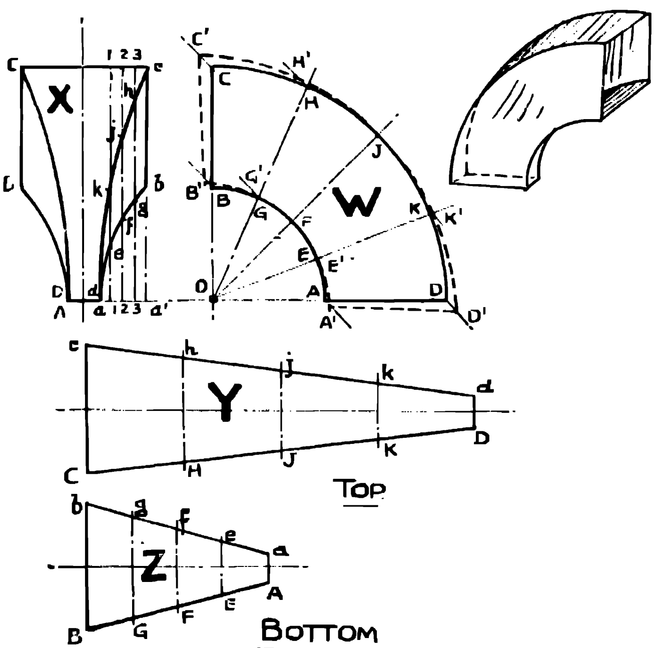


Fig. 236.—Square to rectangular section right-angle bend.

as radius draw an arc to cut line at C in C^1. Repeat the process to obtain points K^1 and D^1 and draw a curve through these points.

The true curve B^1A^1 is found in a similar manner to above, making use of dimensions taken from Fig. Z and commencing from F when drawing arcs. The figure $A^1B^1C^1D^1A^1$ (shown dotted) represents the true shape of pattern for the side.

Square Branch at Right Angles to Circular Pipe (in one piece) (Fig. 237).—In Fig. A the branch J4, 3K is seen arranged at right angles to EF. The end view is illustrated at Fig. B and a plan view at Fig. D.

The development of the branch is shown at Fig. C. To obtain this draw the line LL parallel to JK (Fig. A), making its length equal the sum of all four sides of the branch.

Divide LL as shown, making distance between points equal those for similarly lettered distances in views A and B. Draw perpendicular lines through points L, J, K, etc., and project horizontally the numbered

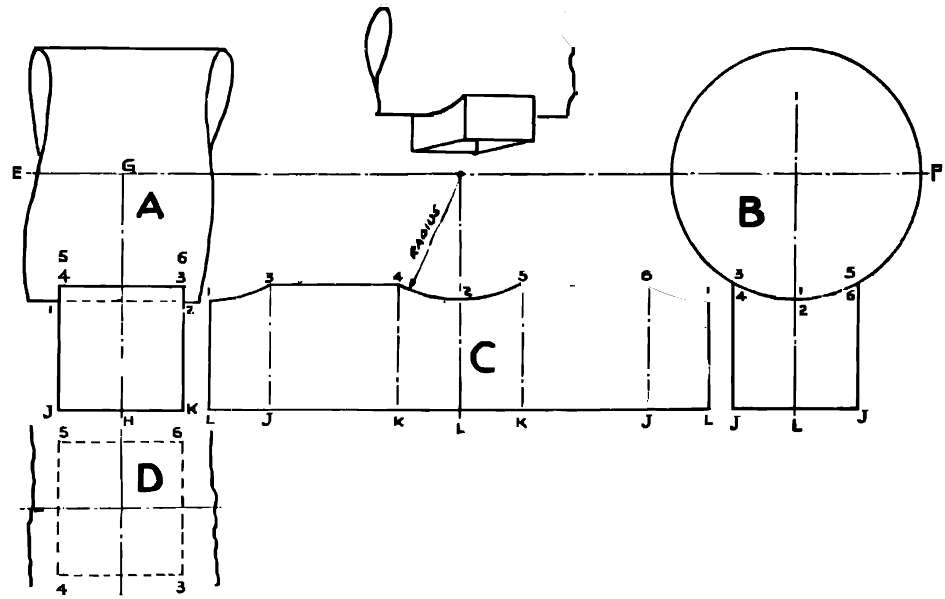


Fig. 237.—Square branch normal to circular pipe.

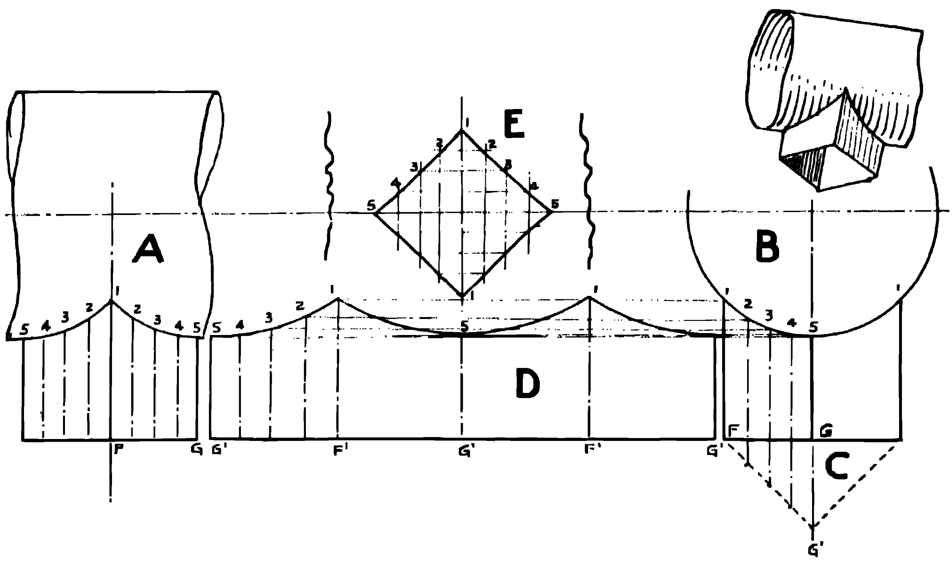


Fig. 238.—Square branch normal to main pipe.

points from view A to correspondingly numbered lines in view C as shown. The radii for curves 1–3 and 4, 2, 5, etc., are equal that of the main pipe.

Fig. D shows the developed shape and dimensions of the hole in the main pipe to accommodate the square branch. It will be noted that the width 5.6 remains unaltered, while the depth 4.5 is equal to the curved length 4.5 as measured in Fig. B.

Square Branch at Right Angles to Main Pipe (in one piece) (Fig. 238).—This problem is somewhat similar to the foregoing except that the branch is turned round with the corners in line with the axis of the pipe.

Figs. A and B show the branch set at right angles to the circular pipe. Fig. C is a half plan of branch. To draw the curve made by the branch meeting the pipe, divide FG (Figs. C and A) into four equal parts and erect perpendiculars through points found, numbering where they intersect the curve of the pipe in Fig. B and projecting horizontally to cut corresponding lines in Fig. A. Draw a curve through the numbered points to complete.

To draw the development of the branch commence by drawing a line G^1G^1 equal in length to the sum of the four sides of the branch. Divide this into four, and erect perpendicular lines through points found.

Divide the distance G^1F^1 into four equal spaces and erect perpendicular lines, number at top and project similarly numbered points from view A to cut lines in view D and draw a curve through points thus found. The curve can be repeated to complete the pattern.

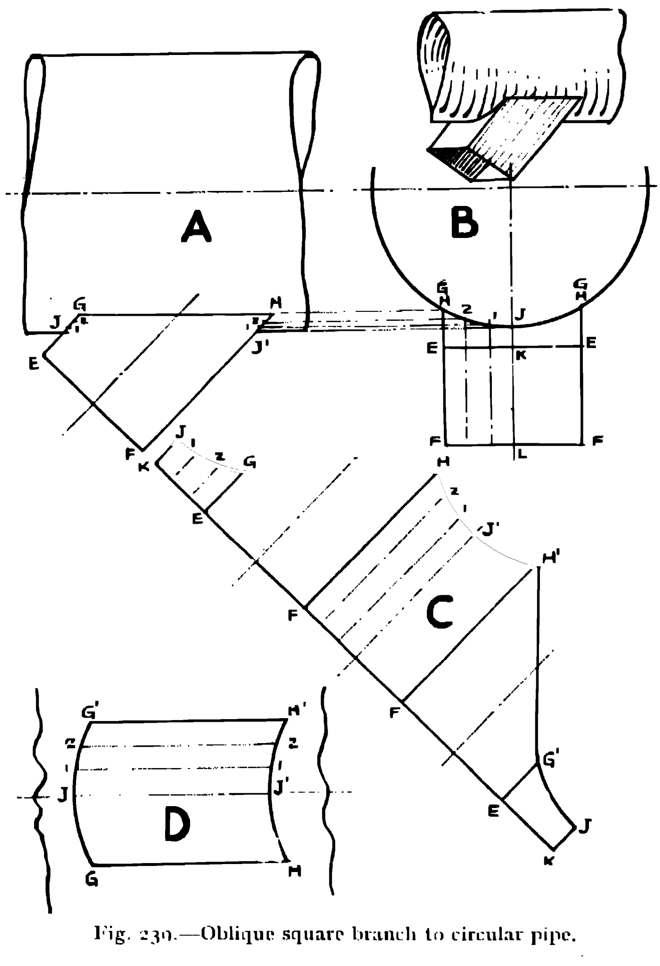


Fig. 239.—Oblique square branch to circular pipe.

The developed shape of hole in the pipe made by the branch is seen at Fig. E. To draw this, make length 5.5 equal that in view A. Divide this distance into eight equal parts and draw perpendiculars.

Now set off parallel to 5.5 lines 4.4, 3.3, and 2.2 at distances 5.4, 4.3, 3.2, and 2.1 as measured at Fig. B, and set off perpendicularly. Through the points of intersection of horizontal and vertical lines draw curves as shown.

Oblique Square Branch to Circular Pipe (in one piece) (Fig. 239).—The front

and end elevations are shown at Figs. A and B respectively. Before proceeding to draw the pattern C, divide FL into three equal parts and erect perpendicular lines to cut the arc GJG in points 1 and 2.

Project latter points horizontally to Fig. A to cut the slanting lines EG and FH in points 1 and 2 as shown.

To draw the development of the branch. In line with EF (Fig. A) draw a line KK equal in length to the sum of the sides of the branch. Divide KK, making distance KE equal half the width of one side of branch and EF, FF, and FE equal the width of one side.

Draw lines through the lettered points perpendicular to KK and parallel to KK project points J, G, H, and J^1, also points 1 and 2 to cut correspondingly lettered and numbered lines as seen at Fig. C.

Join points thus found with curves and straight lines to complete the development of the branch pattern.

Fig. D shows the development of the hole in the pipe made by the branch. To draw this, project points J, G, and J^1H perpendicularly from Fig. A, making the width HH^1 equal the side of the square pipe.

Divide the distance between lines JJ^1 and G^1H^1 into three equal parts and draw lines through these. Project points 1 and 2 from Fig. A to cut lines in Fig. D in developed points 1 and 2 and draw curves GG^1 and HH^1.

Oblique Square Branch Tangential to Circular Pipe (in one piece) (Fig. 240).—Figs. A and B show front and end elevations and it will be seen that the branch is out of centre with the pipe and the side EF parallel with the centre line of same. Draw these views and letter the points as shown.

Divide EE^1 (Fig. B) into four equal parts and erect perpendicular lines through points found to cut the arc JG in points 1, 2, and 3. Project these latter points to Fig. A horizontally and re-number as shown where the lines cut slanting lines FH and EG.

To draw the development of the pattern for the branch. Project a line E^1E^1 parallel to EF (Fig. A). Make the length of E^1E^1 equal the sum of the sides of the square branch and divide into four equal parts as shown. Perpendicular to E^1E^1 draw lines E^1J, EG, FH, F^1K^1, and E^1J projecting points J, G, H, and K^1 parallel to E^1E^1 from Fig. A. Next divide distances E^1E and FF^1 into four equal parts and erect perpendiculars to pass through points found. Project points 1, 2, and 3 from line JG in Fig. A parallel to E^1E^1 to cut the numbered lines between J and G in Fig. C and draw a curve through these points. Repeat with the numbered points 1, 2, and 3 on line KH (Fig. A) projecting same to cut lines between H and K^1 to form the curve HK^1. Join points GH and K^1J with straight lines to complete the pattern.

At Fig. D is shown the hole made in the circular pipe by the penetration of the branch. To draw this, project points J, K, G, and H from Fig. A, making the distance between JK and GH equal JH as measured at Fig. B and setting off this distance normal to JK.

Also set off distances J1, 1.2, and 2.3 in the same manner. Now project the numbered points 1, 2, and 3 from Fig. A to cut similarly numbered lines in Fig. C to form curves JG and KH.

Oblique Square Branch Tangentially Disposed to the Main Pipe (in one piece) (Fig. 241).—This problem is similar to the foregoing with the difference that two of the corners lie parallel to the centre line of the main pipe in this case.

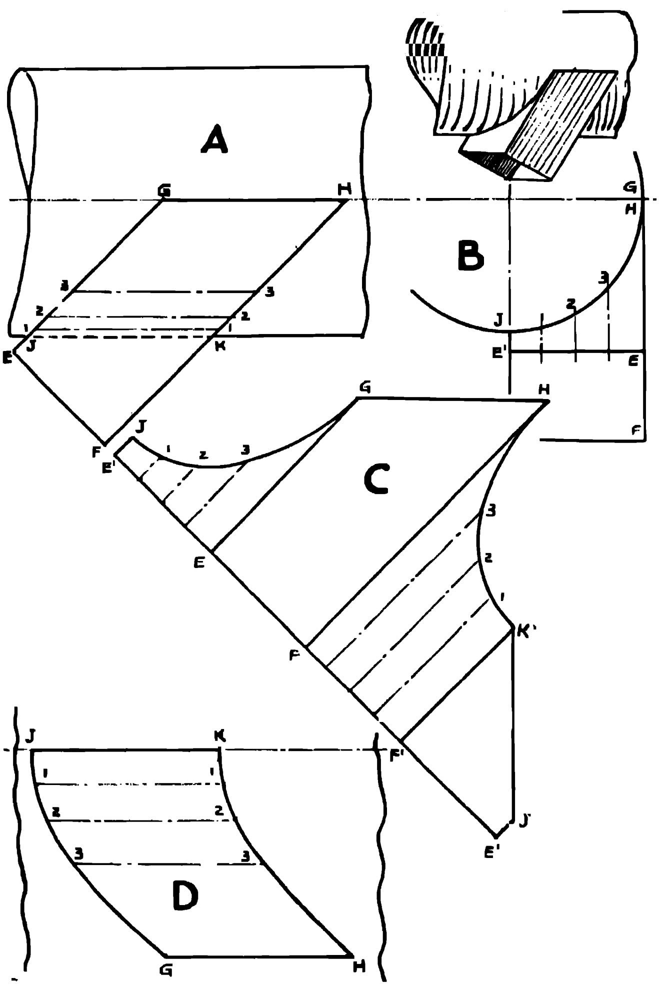


Fig. 240.—Oblique square branch tangential to circular pipe.

Draw a horizontal centre line, also perpendicular to this a centre line to intersect same in G (Fig. B). With G as centre and radius GF describe a circle of EF diameter equal that of main pipe. At E draw a square equal that of the branch and with its centre at a suitable distance from the centre of the main pipe. Divide two sides of the square into equal parts as shown and project lines perpendicularly through division points to cut arc PH in points numbered 1 to 6.

Indicate the diameter of the pipe in Fig. A by parallel lines and draw the centre of the branch JH at the required angle and length. Set off JK and JL so that KL equals the distance across the corners of the square branch. Draw lines KM and LN parallel to JH projecting points M and N horizontally from Fig. B. Project points K, J, J^1, and L from Fig. A to Fig. B, and add lines J^1K, KJ, JL, and LJ^1. To draw the curves MH, MP, PN, and HN divide KJ, JL in Figs. A and B into four equal parts and draw lines through points found to cut the circle at the numbered points 1 to 6.

Project the latter points across to Fig. A to intersect division lines between M and H, H and N, N and P, P and M in points 1, 2, 3, 4, 5, and 6, etc., as shown at Fig. A, and draw curves to join these points.

To develop the pattern for the branch as shown at C, extend KL and set off on this line a distance KK^1 equal to the sum of all four sides of the square branch. Divide KK^1 into four equal parts, KJ, JL, LJ^1, and J^1K^1, and draw perpendicular lines through K, J, L, J^1, and K^1.

Project points M, H, N, and P parallel to KK from Fig. A to cut lines K, J, L, J^1, and K^1 as indicated in similarly lettered points.

Divide up spaces KJ, JL, LJ^1, and J^1K^1 into four equal spaces, and draw lines perpendicular to KK through points found. Number these lines as shown, and project similarly numbered points from Fig. A parallel to KK to cut these.

Draw curves through points of intersection to form curves MH, HN, NP, and PM^1, thus completing the pattern Fig. C.

Fig. D illustrates the developed form of the hole in the pipe to accommodate the branch pipe. To draw this, project point P from Fig. A and draw lines 6.6, 5.5, 4.4, MN, 3.3, 2.2, 1.1, and H parallel to each other at distances apart measured at Fig. B. Now project perpendicularly from Fig. A the numbered and lettered points 1 to 6 and M, P, H, and N to cut corresponding lines in Fig. D. Draw curves MP, PN, NH, and HM to complete the development of the hole at Fig. D.

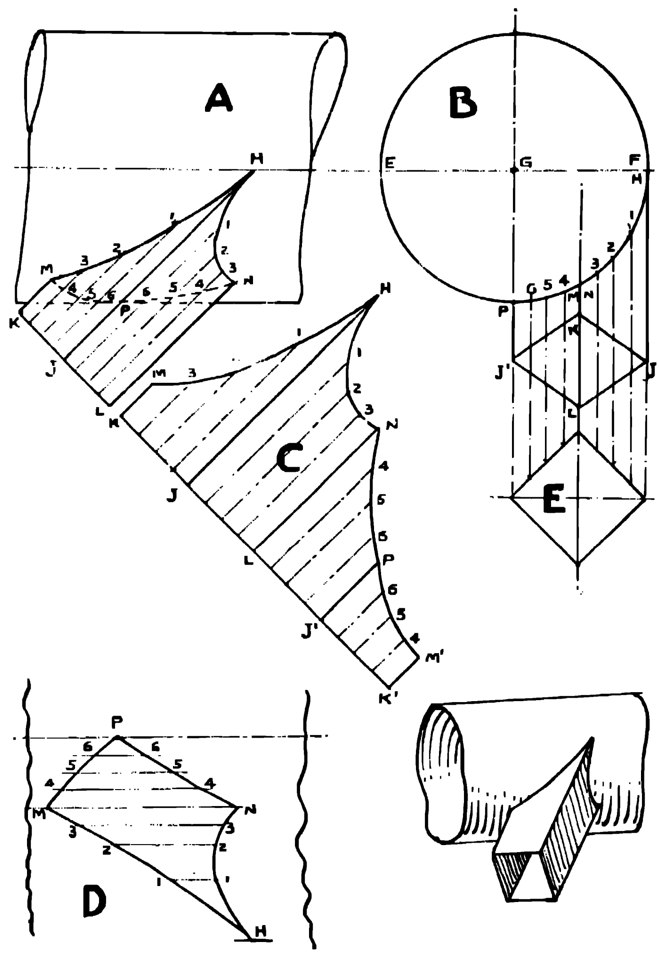


Fig. 241.—Oblique square branch tangential to main pipe.

Twin Branches Normal to Main Pipe (Fig. 242).—Draw the front and end elevations A and B respectively, showing the disposition of the branch pipes in relation to the main pipe.

Describe semicircles on the bases KL and CD, and divide each into four equal parts. Draw perpendicular lines through all points M, and where they cut the arc of the main pipe, Fig. B, project across to cut similar lines in Fig. A; also project points H, G, and J from Fig. B to Fig A, and draw a curve through points F, M, H, M, and F. Draw perpendicular lines GG (Fig. B) and GG^1 (Fig. A). Divide arc G^1G^1 into six equal parts. Erect perpendicular lines through points 1 and 2 thus found. Divide arc CG^1 (Fig. B) into three equal parts and number as shown, projecting same perpendicularly to cut JG in points 1 and 2. Project the latter points horizontally from Fig. B to Fig. A to cut similarly numbered lines. Connect points J, 2.1, and G with lines as shown. To draw the pattern (Fig. P) for the branch, commence with a horizontal line CC equal in length to the circumference of the branch pipe. Divide CC into eight equal parts, letter points as shown, and erect perpendiculars. The heights of lines CJ, MM, KF, etc., are as measured in Fig. A, and curves are drawn to connect all points as illustrated.

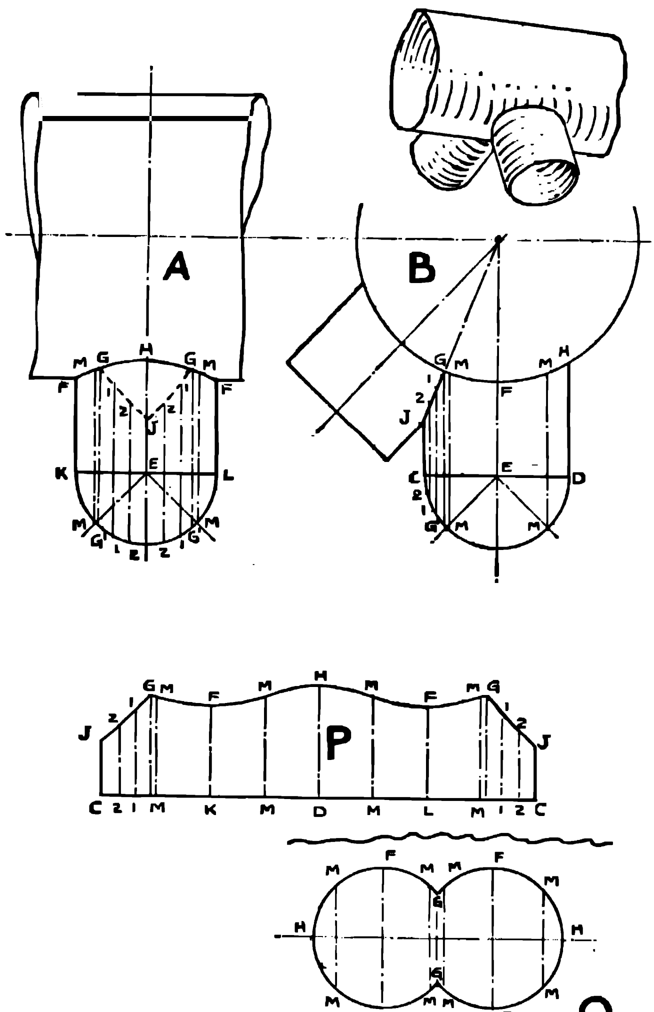


Fig. 242. Twin branches normal to main pipe.

Fig. Q illustrates the development of the hole in the main pipe to accommodate the twin branches. This is drawn as follows:

Draw a horizontal centre line and mark off on this HH equal twice GH (Fig. B). Bisect HH and draw a line GG equal to GG (Fig. A). Parallel to GG, and at distances apart measured at Fig. B, draw lines MM and FF, whose lengths are measured at Fig. A. A curved line drawn through points H, M, F, M, G, etc., completes the development of the hole in the main pipe.

Twin Branches at an Angle to Main Pipe (Fig. 243).—Draw the front elevation (Fig. A) and view (Fig. B), showing branches in correct relation to each other and to the main pipe.

Add semicircles C and D, and divide these into equal parts and parallel

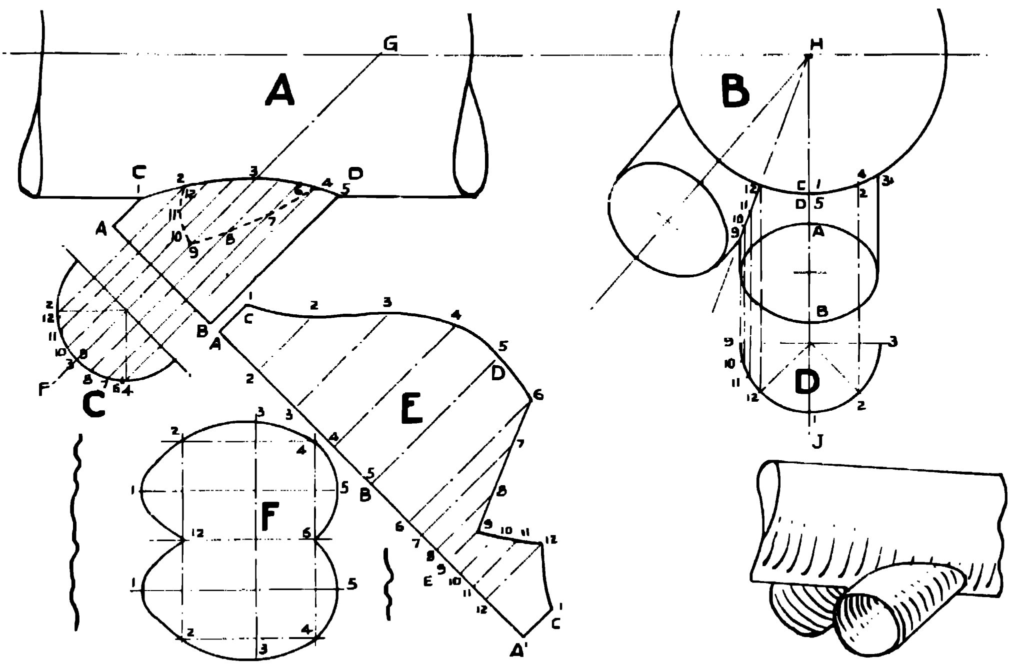


Fig. 243.—Twin branches at an angle to main pipe.

with centre lines FG and JH, project up lines. Where lines 2 and 3 intersect the circle of main pipe in points 2 and 3, Fig. B, project these across horizontally to cut lines 2, 3, and 4 in Fig. A. Draw a curve through points 1, 2, 3, 4, and 5. Referring to Fig. B, project perpendicularly point 12 to the semicircle D. Divide the arc 9–12 into equal parts and project lines perpendicularly through points 10 and 11 to view B. Mark off equal arcs 9–12 and 9–6 (Fig. C), dividing each into three equal parts. Project points thus found with lines parallel to FG to the elevation (Fig. A). Points 6 to 12 (Fig. B) are now projected horizontally to Fig. A to cut similarly numbered lines and a curve 6–12 drawn.

To draw the development of the branch as seen at Fig. E. Draw a line AA^1 equal in length to the circumference of the branch. Bisect AA^1

in B, and divide AB into four equal parts, drawing lines normal to AA^1 through points thus found. Next bisect BA^1 in E, and set off on either side distances 9–6 and 9–12, as measured at Fig. C. Divide the distance 6–12 into equal parts as shown, and erect perpendiculars through points found. Parallel to AA^1 project all numbered points in Fig. A to cut correspondingly numbered lines in Fig. E, and draw curves through points thus obtained. The figure AA^1C^1CA is the development of one branch pipe. Fig F. shows the development of the hole in the main pipe. This is obtained as follows: draw a horizontal line 12–6, projecting these points from Fig. A. Also project points 1, 2, 3, 4, and 5, and make the perpendicular distances between the lines 1–5 and 12–6, etc., equal those measured at Fig. B. Complete by drawing curved lines to join all numbered points as shown.

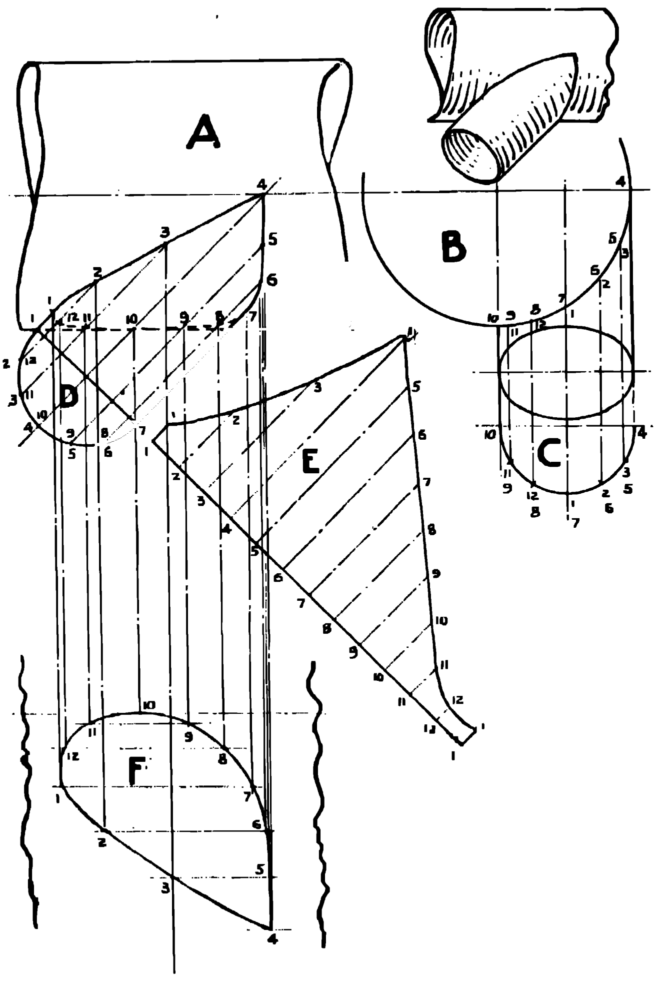


Fig. 244.—Oblique branch out of centre of main pipe.

Oblique Branch Out of Centre of Main Pipe (Fig. 244).—Draw the main pipe and branch in relation to each other as shown at Figs. A and B.

The curve made at the junction of the pipes as seen at Fig. A is obtained as follows: draw semicircles D and C and divide these up equally as shown. Project lines through points thus found parallel to the centre line of the branch in each view. Number the points as shown in each view and project horizontally numbered points in Fig. B to Fig. A to cut correspondingly numbered lines there. Draw a curve through points of intersection to complete Fig. A.

The development of the branch pipe is shown at Fig. E, and this is drawn as follows: draw a line 1–1 in line with the base of the branch at Fig. A and make the length equal the circumference of the branch pipe. Divide this into twelve equal parts and erect lines perpendicular to the base line 1–1. Now parallel to the base line project all numbered points from Fig. A to Fig. E to cut similarly numbered lines and draw a curve through the points of intersection to complete Fig. E.

The development of the hole in the main pipe is seen at Fig. F. This is obtained by the perpendicular projection of numbered points from Fig. A, making the distances between horizontal lines the same as those between similar points at Fig. B. A curve drawn through all points thus found completes the development of the hole in the main pipe.

Gusset for Pipes Meeting at Right Angles (Fig. 245).—It is sometimes advantageous with pipe branches to assist the flow from the main pipe to the branch by adding a gusset at the point of junction.

Fig. A shows the elevation of such a gusseted branch where both pipes are of the same diameter.

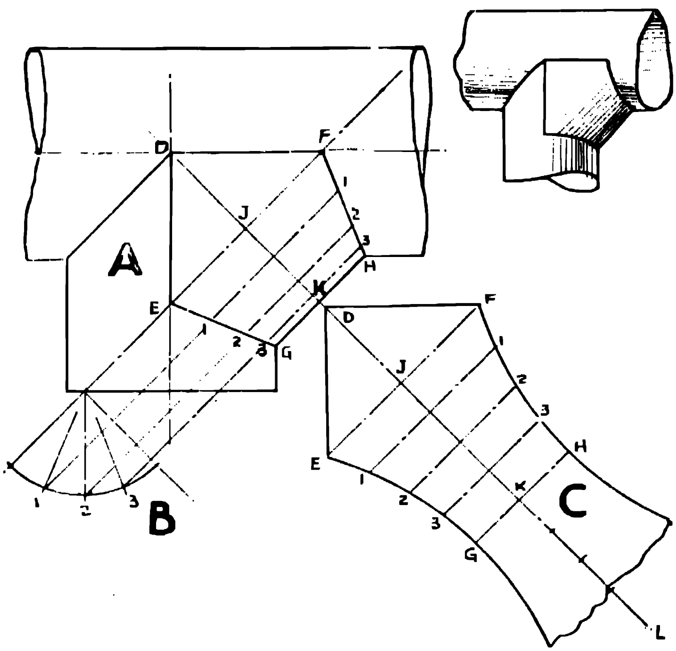


Fig. 245.—Gusset for pipes meeting at right angles.

Draw Fig. A, showing the branch pipe in relation to the main pipe. Add the centre line DL at 45 degrees and decide upon the position of GH. Parallel to GH, mark off JK, equal half the diameter of the branch, and draw the line EF through this normal to DL. Join points EG and FH. Add a quarter circle of radius JK as seen at Fig. B, and divide same into four equal parts. Number the points 1, 2, and 3, and parallel to EF project these to Fig. A to form lines 1.1, 2.2, and 3.3. To draw the development Fig. C, commence with a line GH normal to DL. Next set off J at a distance from K equal quarter the circumference of branch. Divide this into four equal parts, and draw lines through points found normal to DL. Now set off JD equal JD (Fig. A) and EF equal EF (Fig. A). Project numbered lines 1.1, 2.2, and 3.3 from Fig. A to cut

similarly numbered lines in Fig. C. A curve through points E, 1, 2, 3, G, and F, 1, 2, 3, H, also straight lines ED and DF, completes one-half of the development of the pattern for the gusset. These gussets can be applied to pipes of any diameter and branches set at any angle, and are occasionally fitted at both sides of a pipe junction.

Rectangular Hopper (in four pieces) (Fig. 246).—The method of development given in this case is suitable where the corners are to be butted as in cases where they are to be secured by welding or by means of bolted corner angles. The full lines at Figs. A and B indicate the front and semi-end elevations of the hopper, and a plan is shown at C. Draw Figs. A and B and letter points as illustrated.

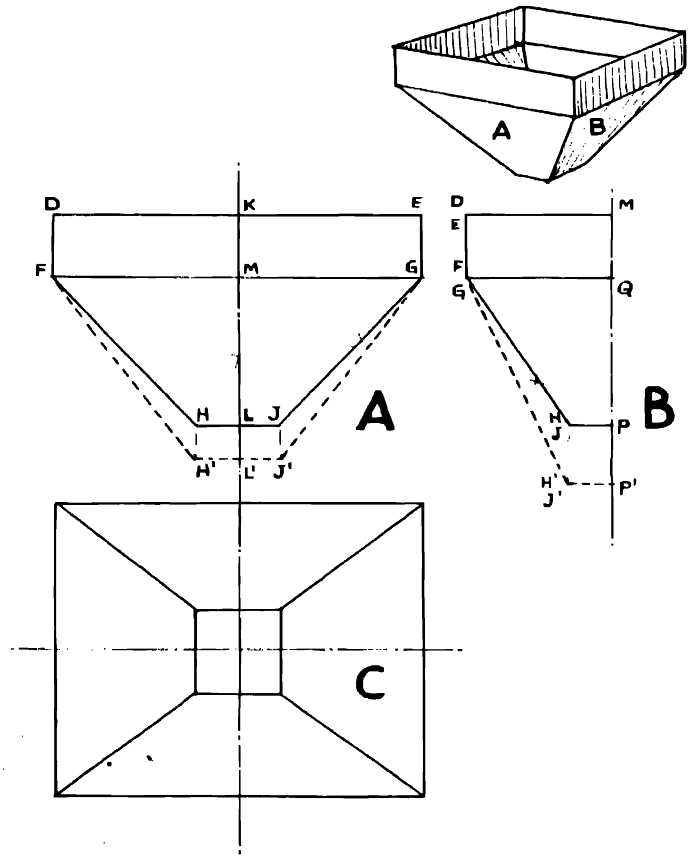


Fig. 246.—Rectangular hopper with square outlet.

To develop the front (Fig. A) in position, mark off ML^1 equal GJ (Fig. B). Through L^1 draw a line H^1J^1 projecting points perpendicularly from H and J. Join H^1F and J^1G. D, E, G, J^1, H^1, F, D is the development of the front and back plates of the hopper.

The development of the side (see Fig. B) is obtained by making QP^1 equal GJ (Fig. A), drawing P^1J^1 parallel to PJ and joining J^1 to G to complete the half development, which is next duplicated.

Rectangular One-sided, Tapered Hopper or Spout (in four pieces) (Fig. 247).—Figs. A, B, and C illustrate front, end, and plan views respectively of a one-sided type of hopper, and the developments of the surfaces are indicated in position in Figs. A and B.

The true dimensions of the perpendicular sides GEFHG and GACEG are obviously those seen in Figs. A and B. The other two sloping sides

are shown developed in position and indicated by dotted lines. At Fig. A the side BACDBA is developed by drawing C^1D^1 parallel to CD, making AC^1 equal AC (Fig. B). Similarly, the side BDFHB is developed by drawing F^1D^1 parallel to FD, and the distance HF^1 equal HF as measured at Fig. A.

Rectangular Tapered Hopper, Hood, or Spout with Compound Tapers on Two Sides (in four pieces) (Fig. 248).—Front, side, and plan views of this hopper are shown at Figs. A, B, and C respectively. The full lines are the apparent lines of the object, and the dotted lines show the developed sides in position.

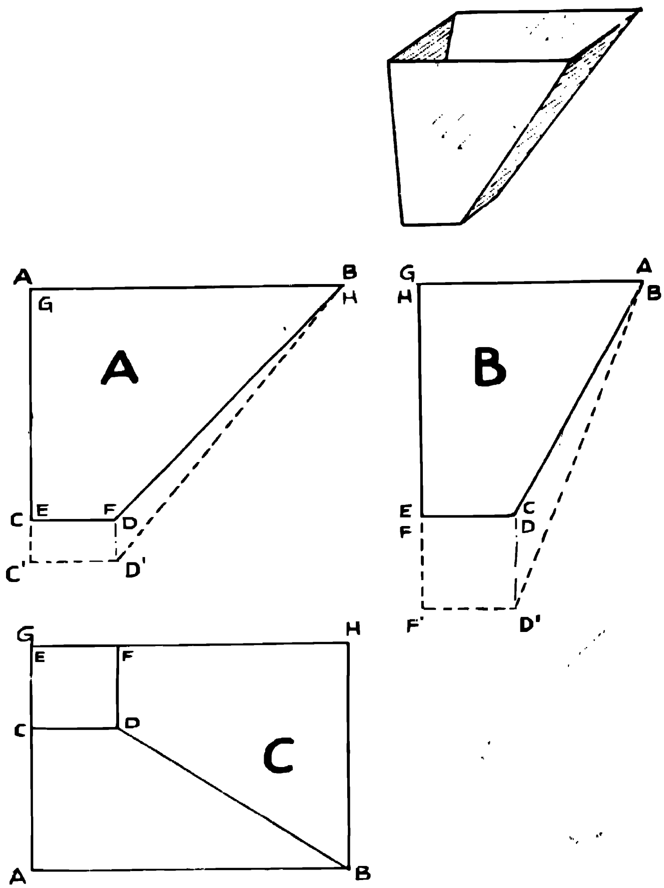


Fig. 247.—Tapered hopper or spout.

To develop the front, back, and sides (Fig. A) draw the line C^2D^2 at a distance HK^2 equal B^1C^1 (Fig. 8). Also mark off HJ^1 equal B^1E^1 (Fig. B) and draw E^2F^2 through J^1, making the length of E^2F^2 equal EF. Join A, E^2, C^2, D^2, F^2, and B with a dotted line to complete the pattern for the front and back.

To develop the pattern for the side (see half development, Fig. B), set off in Fig. B a distance LM^2 equal to BF (Fig. A), making the line M^2E^2 equal E^1M. Also set off M^2N^2 equal FD (Fig. A), making N^2C^2 equal NC^1. Join C^2, E^2, and B^1, thus completing the half pattern for the end of the hopper.

Tapered Cover or Screen in One Piece (Fig. 249).—Draw views A, B, and C as illustrated by full lines. To draw the development of the sloping sides and top proceed as follows:

Commencing with the top surface $C^1D^1B^1A^1$, draw parallel to A^1B^1 a line A^3B^3 at a distance from C^1D^1 equal to C^1A^1 (Fig. B). Make A^3B^3 equal A^1B^1 by projecting individual points perpendicularly and join A^3C^1 and B^3D^1.

Similarly the surfaces CC^1A^1AC and DD^1B^1BD are developed by drawing parallel to CC^1 and DD^1 at distances AC and DB respectively (Fig. C) to obtain the lines A^2A^3 and B^2B^3 respectively. Project points A^3 and B^3 horizontally from A^1 and B^1 and join A^3C^1 and B^3D^1 to complete the pattern as shown.

Tapered Hopper with Square Outlet (in four pieces) (Fig. 250).—Figs. A, B, and C represent the front, end, and plan views of the hopper. In this example none of the apparent surfaces is a true pattern owing to the compounding of the tapers.

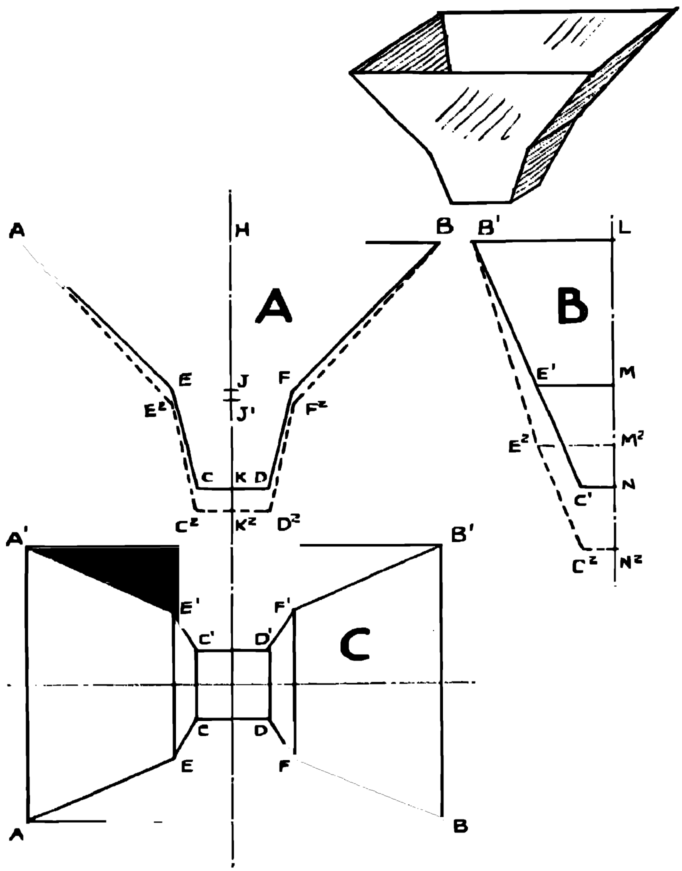


Fig. 248.—Hopper with compound tapers.

Before proceeding to develop the surface shown at Fig. A, it should be explained that this side will require to be bent along lines CD and AD in order to bring the edges together.

To develop the surface, draw an extended line AG normal to CD, and extend CE (Fig. B) to cut AA^1 in C^1. Measure C^1A and set off this distance normal to CA (Fig. A). Measure CC^1 and set off along extended line GA to obtain A^2. Parallel and equal to AB draw A^2B^2. Join CA^2 and DB^2D. The surface $FECA^2B^2DF$ is the development of the side shown at Fig. A.

To obtain the patterns for the front (Fig. B) set off A^1A^2 parallel to AA^1 at a distance from C^1C equal to CA (Fig. A). Join A^2C^1 and A^1C.

Similarly for the pattern of the back draw B^1B^2 parallel to BB^1 at a distance from DD^1 equal to DB (Fig. A). Join B^1D and B^2D^1 to complete the development of pattern.

Rectangular Tapered Chute (in four pieces) (Fig. 251).—Draw the elevations A and B and add a plan C. To develop the pattern for the side seen at Fig. A draw, parallel to CD, a line C^1D^1 at a distance normal to AB

equal to AC. Join C^1A and D^1B to complete.

The development of the front (Fig. B) is obtained by drawing line C^2C^3 parallel to CC^1 at a distance equal to CA (Fig. A) normal to AA^1. Join C^3B^1 and C^2B. The back is drawn by a similar method, making D^2D^3 parallel to DD^1 at a distance BD normal to AA^1. Complete the development of pattern by joining D^2B and D^3B^1.

Internal Deflectors for Tapered Chute (Fig. 252).—When a chute or hopper similar to that shown is used to convey grain, etc., it will frequently be found that only the mass of material immediately above the outlet moves, leaving the material at each side stationary. To overcome this difficulty, the writer has devised and fitted deflectors to the inside of chutes with satisfactory results. The idea is to split up the moving mass, and by shedding this to either side to keep the whole moving and thoroughly mixed.

Fig. A shows the front view of a hopper to which V-shaped

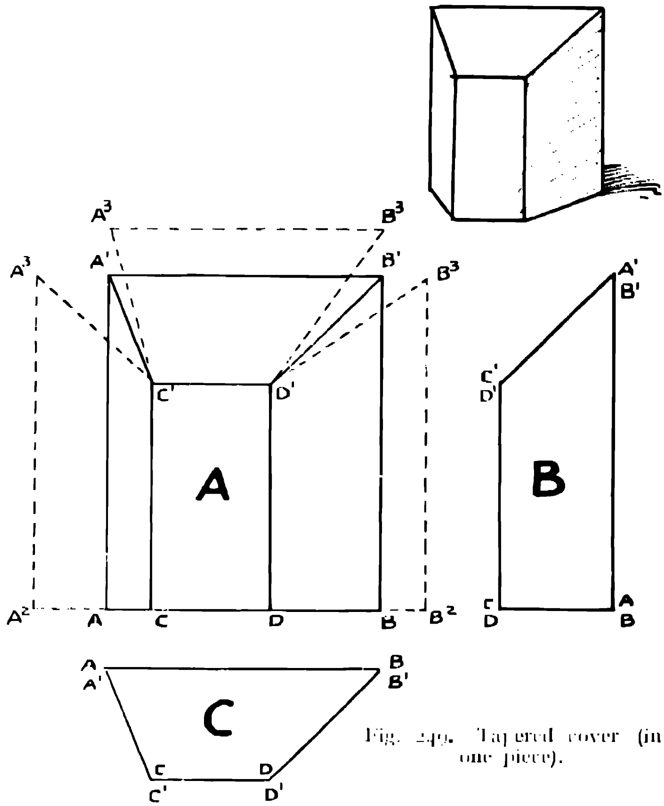


Fig. 249. Tapered cover (in one piece).

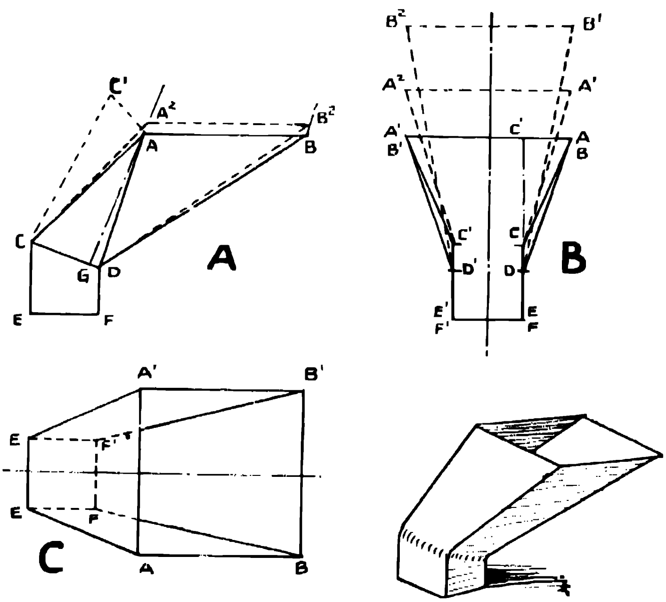


Fig. 250.—Tapered hopper with square outlet.

deflectors are fitted. To explain the method of development of the deflectors, it will be sufficient to deal with one only. In Fig. A is seen the two wings, AB and BC. Fig. B is an end view of the hopper. To develop the pattern for the wing AB, draw A^2A^3 parallel to AA^1 at a distance equal to AB normal to BB^1. Join A^2B and A^3B^1 to complete the pattern for one half wing of the V deflector. The small side deflectors are developed in the same way as that just described.

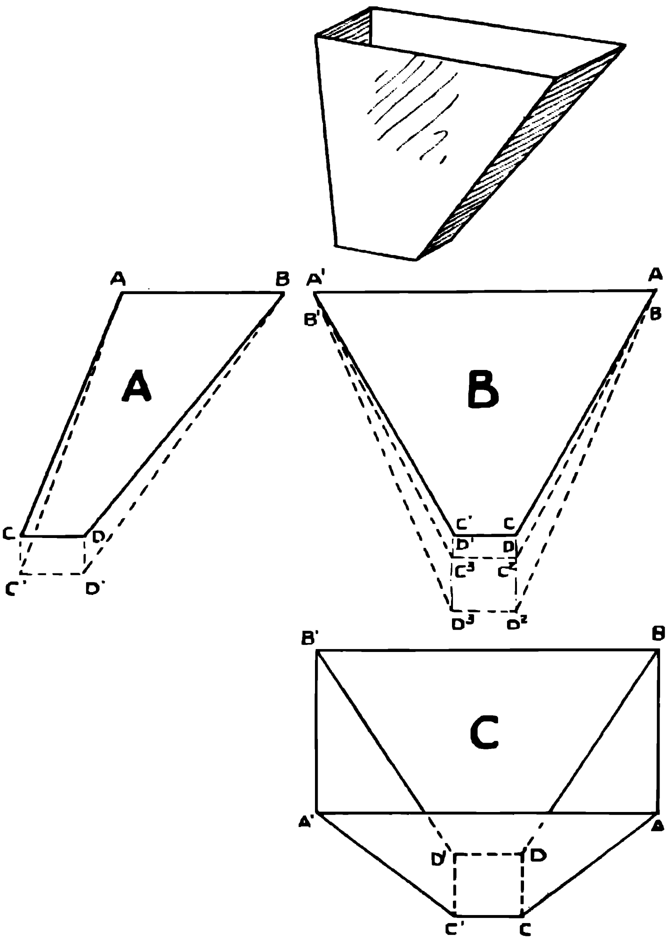


Fig. 251.—Rectangular tapered chute.

Pyramidical Pipe Branch at Right Angles to Main Pipe (in one piece) (Fig. 253).—Draw the front elevation A and end elevation B, showing the branch in position. Divide FA (Fig. B) into four equal spaces, and draw radial lines to the apex C, cutting the circle of the main pipe in F, G, H, and J. With CA radius, describe an arc AK. To develop the branch, commence by drawing AD (Fig. C) tangential to arc AK, the point D to be located on an extension of the base line DA (Fig. B). Draw radial lines DC and AC and divide AD into eight equal parts. Add radial lines through points thus found to apex C. Parallel with the base line AD project A^1 (Fig. B) to cut CD (Fig. C) in A^2. Project points F, G, H, and J (Fig. B) horizontally to cut CA in F^1, G^1, H^1, and J^1.

With C as centre and CF radius, cut line CF (Fig. C) in F^2, also with CA^2 radius cut CA, CB, CC, and CD in points A^2. Next construct the offset diagram D. Draw a perpendicular line, and selecting a point C on this, set off distances CJ^1, CH^1, and CG^1 (see Fig. B). Draw horizontal lines through these points. Measure horizontal distances between GH

and J and centre line CF (Fig. B), and set off these distances along corresponding lines in the offset diagram. Now set the compasses to CJ^2, CH^2, CG^2 (Fig. D), and with C as centre set off these radii to cut CJ,

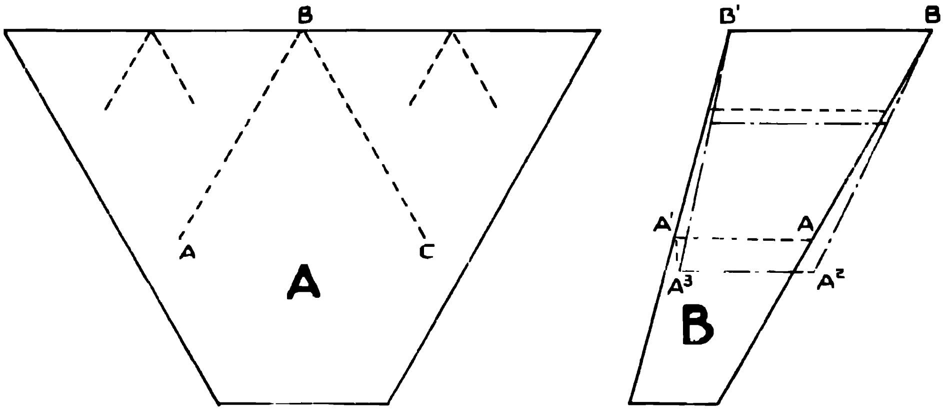


Fig. 252.—Internal deflectors for tapered chute.

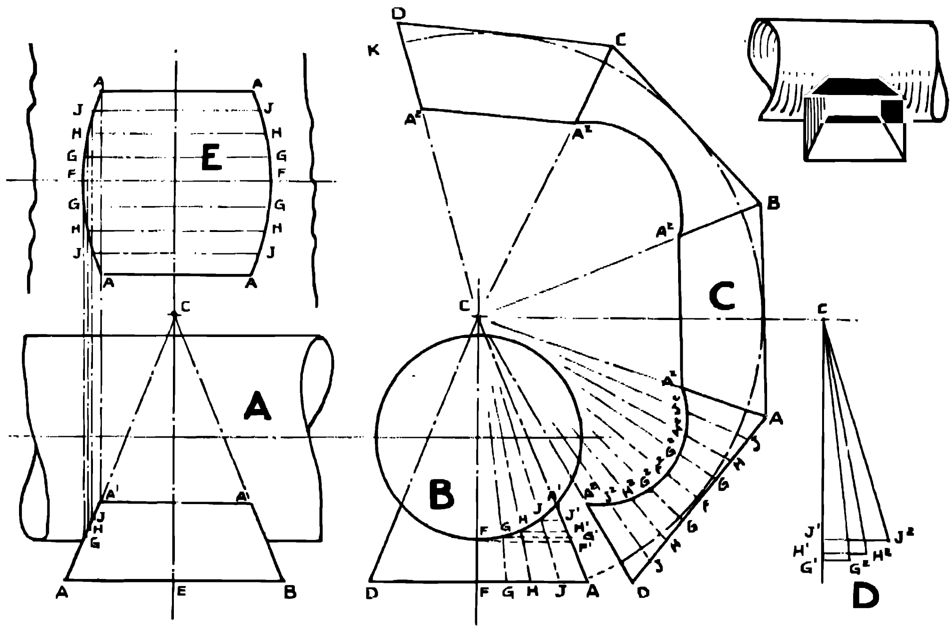


Fig. 253.—Pyramidical branch normal to main pipe.

CH, and CG in J^2, H^2, and G^2. Complete the development by joining points A^2 with curves and straight lines as shown.

Fig. E shows the development of the hole in main pipe. To draw this, commence with horizontal lines FF, GG, HH, JJ, and AA, making the distance between these lines equal FG, GH, HJ, etc., as measured at

Fig. B on the circle of pipe. Project points F, G, H, J, and A^1 horizontally from Fig. B to diagonal lines CA and CB (Fig. A), and re-project points perpendicularly to cut similarly lettered lines in points A, J, H, G, and F. Complete Fig. E by drawing curves to pass through the latter points as shown.

Sphere Penetrated by Square Pyramid (Fig. 254).—In this example it will be noted that the apex of the pyramid is located above the centre of the sphere. Draw the elevation A of pyramid, showing the sphere in the desired position. Extend CB to cut the sphere at G and bisect GF in N.

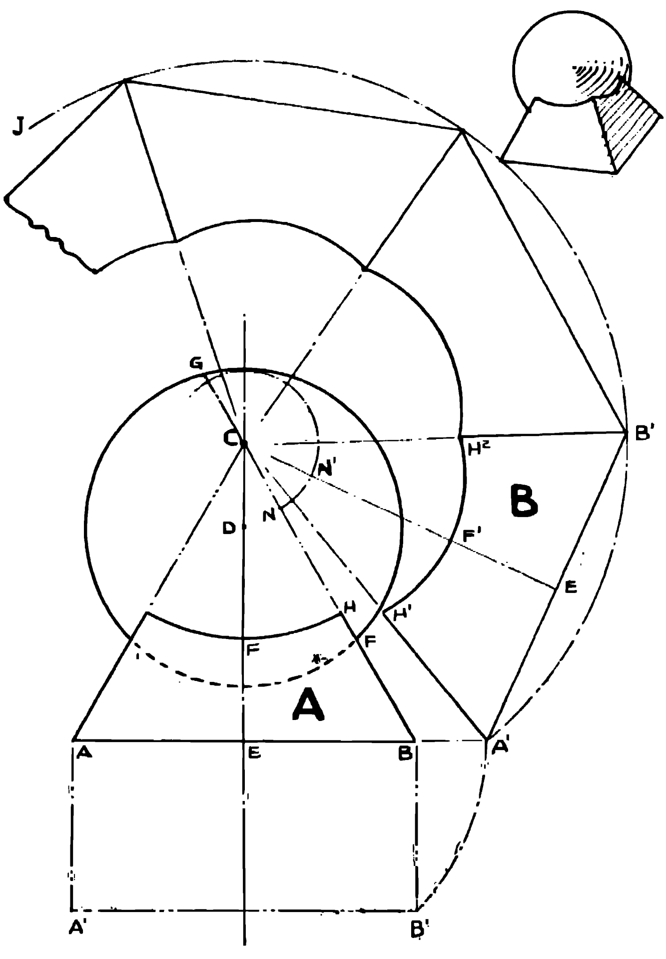


Fig. 254.—Sphere penetrated by square pyramid. (Apex of pyramid above centre of sphere.)

Drop a perpendicular line BB^1 equal half the length of base AB.

Extend line AB, and with E as centre and EB^1 radius, describe an arc to cut the extended base line in A^1. Now with C as centre and radius CA^1, describe an arc A^1J, and step off on this four chordal distances A^1B^1 equal to AB. Join points A^1 and B^1 with radial lines to C.

Bisect A^1B in E^1 and draw a radial line to C. With C as centre and radius CN, cut line CE^1 in N^1, and with this point as centre and NF radius describe arc H^1H^2. This completes the development of one side of the pyramid. The other three sides are drawn by the same method as illustrated at Fig. B.

Sphere Penetrated by Square Pyramid (Fig. 255).—In this example the apex of the pyramid coincides with the centre of the sphere.

Draw the pyramid ABCA with the sphere at the apex. Extend the base line AB, and with C as centre and radius CB, describe an arc BE.

Tangential to this, draw a line A^1B^1 equal AB with A^1 located on the extended base line. Join A^1C and B^1C, and with C as centre and CD (the radius of the sphere) as radius, describe arc DD^1, thus completing the development of one-quarter of the pattern for the pyramid. This can be repeated for the other three sides.

Equal Tapering Object, Circular at Base, Square at Top (Fig. 256). —This object may be treated as a cone for development purposes. Draw the elevation X, making AB the diameter of the circular base and CD the distance across the corners of the square top. The perpendicular height is EF.

Extend AC and BD to intersect in G, the apex of the cone. Add a half plan Y.

To develop the pattern Z: with G as centre and GB radius, describe an arc BB^1 whose length equals the circumference of the circular base AB. Divide BB^1 into four equal parts BJ, JA, AJ^1, J^1B^1 and add radial lines through these points to G. Set off distances GH, GC, etc., equal GH, and connect these points with straight lines.

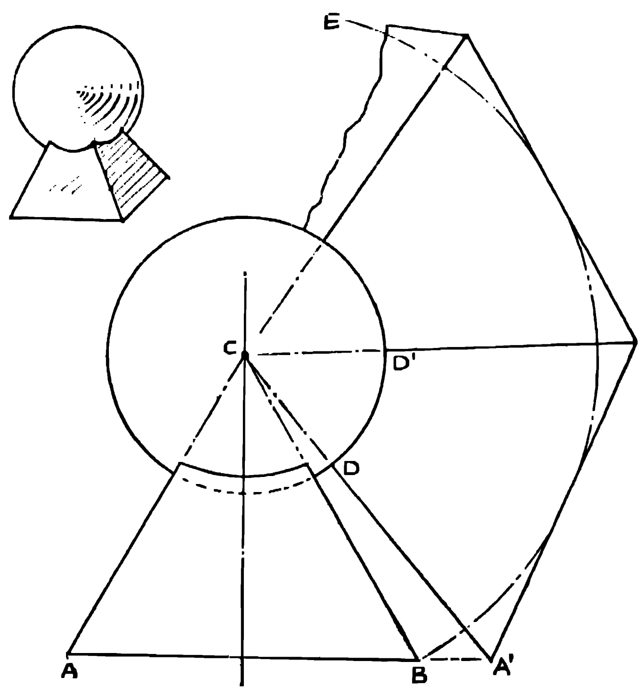


Fig. 255.—Sphere penetrated by square pyramid. (Apex of pyramid on centre of sphere.)

Subdivide BJ, JA, etc., adding points K, L, L^1, and K^1. Join DK, HK, HL, CL, etc., to complete the development of the pattern. The latter lines are the bending lines for the triangular, flat portions. Curved parts are formed by bending along radiating lines as shown between B and K (Fig. Z).

Object with Circular Base and Square Branch at Top at Angle (Fig. 257).—This object cannot be developed as a cone and the method used consists in obtaining the true lengths of lines by triangulation.

Commence by drawing the elevation Fig. W, showing the branch at the top of the object at the required angle. The diameter of the base is AB, and the size of the square branch CD.

Add a half plan X, projecting points E and F perpendicularly from the elevation, and making EE^1 equal half CD. Divide the semicircle

AB into equal parts as shown and add lines to radiate from points E^1 and F^1 to A, M, L, K, J, H, and B.

Before proceeding with the development of the pattern, draw the offset diagram Y. To construct this draw perpendicular and horizontal lines as shown to intersect at E^1F^1. Measure the perpendicular height of point F (Fig. W), and mark this up from E^1F^1. Also mark up the height of point E.

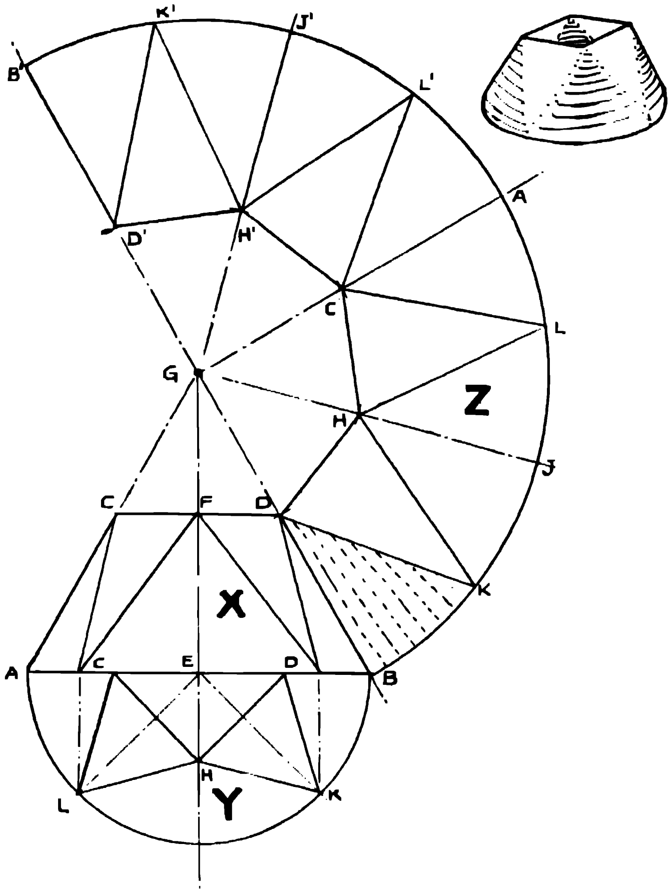


Fig. 256.—Object with circular base and square top.

Now referring to Fig. X, measure distances F^1K, F^1J, F^1H, and F^1B, and set these off horizontally to the right of the perpendicular line in the offset diagram. Also measure distances E^1K, E^1L, E^1M, and E^1A (Fig. X), and set these off to the left of the perpendicular line in the offset diagram (Fig. Y). Join points H, J, B, and K to F, and points A, K, M, and L to E to obtain the true lengths of these lines.

To commence drawing the pattern, make the line FF^1 (Fig. Z) normal to FB. The diagonal distance F^1B should check up to FB in Fig. Y. Now with B as centre and radius BH (Fig. X), describe an arc at H. Re-set compasses to FH (Fig. Y) and describe another arc to cut the previously drawn arc in point H. With point H as centre and radius HJ (Fig. X), describe an arc at J in the development. Again re-set compasses to FJ (Fig. Y), and with F^1 as centre describe an arc to cut the previously drawn arc in point J. Again, from point J describe an arc of JK radius to be cut by an arc of FK radius in point K. Join F^1K and draw a curve through BHJK.

Now with F^1 as centre and radius FE (Fig. W), describe an arc at E^1 to be cut in E^1 by an arc of KE radius (Fig. Y) struck with K as centre.

Join KE^1 and proceed to construct the section E^1, A, KE^1 as previously described, but using radii EL, EM, and EA as obtained from Fig. Y. Next with compasses set to EA (Fig. W) and A as centre (Fig. Z), describe an arc at E to be cut by an arc struck from E^1 with radius E^1E (Fig. X). Join EA to complete one-half of pattern.

Conical Branch at Right Angles to Circular Pipe (Fig. 258).—Draw the elevation X, making AB the base of the cone and CD the height. Add an end elevation Y, again drawing the cone and describing the arc GH of the pipe with radius CB^1.

Now add arcs W to each view, the radius being equal to DB. Divide these up into equal spaces as shown, and project points perpendicularly to the base and from thence adding radial lines to the apex C in each case. To draw the curve made at the intersection of the cone and pipe (Fig. X) project horizontally points E^1, F^1, and D^1 from Fig. Y to cut lines EC, FC, and DC in points E^1, F^1, and D^1. Draw a curve through latter points.

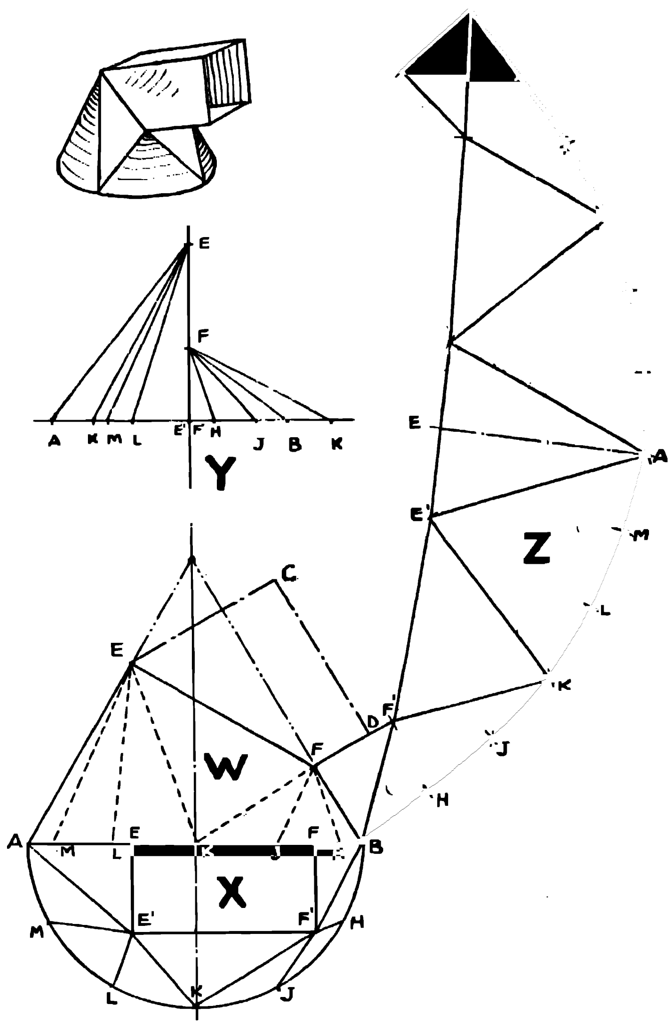


Fig. 257.—Object having circular base and square branch at top.

To draw the pattern (Fig. Z) for the conical branch: with C as centre and CD radius, describe arc D*d*, making the length equal the circumference of the cone base. Divide this arc into twelve equal spaces and add radial lines as shown.

In Fig. Y project horizontally points B^1, E^1, and F^1 to cut CD in points B^2, E^2, and F^2. Next, with compasses set on C as centre, draw an arc of CF^2 radius to cut radial line CF in F^2. Repeat with radii CE^2 and CB^2

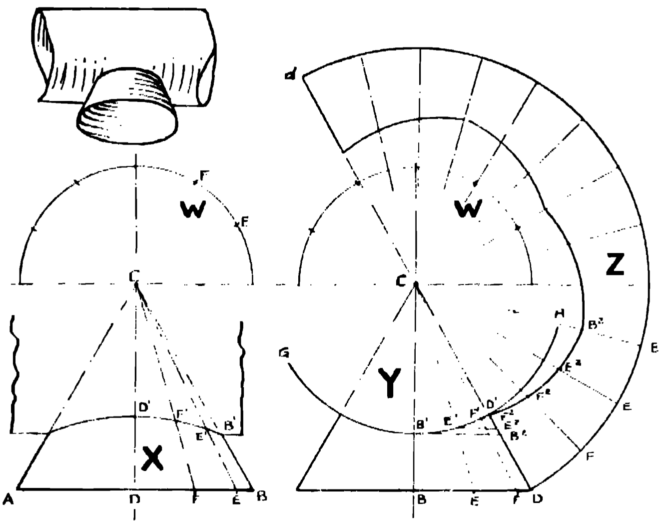


Fig. 258.—Conical branch normal to main pipe.

cutting lines CE and CB in E^2 and B^2. This completes one-quarter of the development of the pattern, and this may be repeated.

Pipe with Obliquely Set Conical Branch (Fig. 259).—Draw the elevation X, showing the cone at the required angle in relation to the pipe. Add a half end view Y. To draw this describe a semicircle for the pipe, also add semicircles W of DB radius. Divide latter semicircles into six equal parts and project to the base parallel to CD. Add radial lines shown and letter same.

To draw the cone at Fig. Y, draw lines parallel to the pipe to pass through points A, H, G, D, F, E, and B, and carry these through into

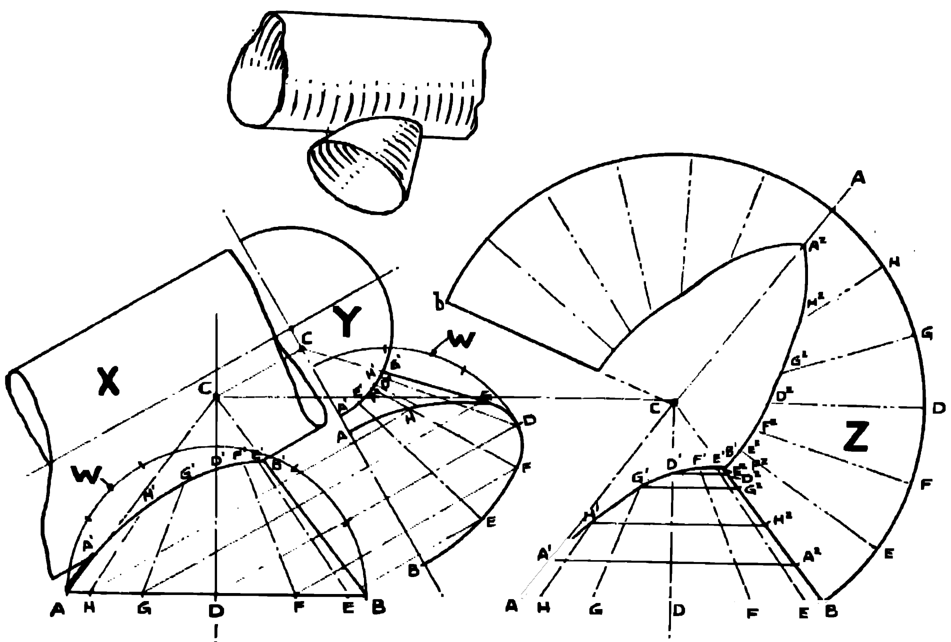


Fig. 259.—Pipe with oblique conical branch.

Fig. Y. Parallel to CB (Fig. Y) project points of division of the semi-circle W to intersect lines just drawn in points A, H, G, D, F, E, and B, and draw a curve through these points. To draw the curve A^1B^1 (Fig. X) project the lettered points E^1, F^1, G^1, D^1, and H^1 from Fig. Y to cut radial lines CE, CF, CG, CD, and CH in E^1, F^1, G^1, D^1, and H^1 and draw a curve through these points.

To draw the pattern, repeat the view of the cone as shown at Fig. X and project points A^1, H^1, G^1, D^1, F^1, and E^1 parallel to the base to cut the side of cone CB in A^2, H^2, G^2, D^2, F^2, and E^2.

Now with centre C and radius CB, describe an arc B*b* equal in length to the circumference of the cone base. Divide this into twelve equal parts, and with centre C and radius CE^2 draw an arc to cut radial line CE in E^2. Repeat, using radii CF^2, CD^2, CG^2, CH^2, and CA^2, cutting radial lines CF, CD, CG, CH, and CA in F^2, D^2, G^2, H^2, and A^2. Draw the curve B^1A^2 and repeat to complete the pattern.

Conical Branch at Right Angles to Main Pipe (Fig. 260).—In Fig. X draw the conical frustum $A^1B^1FEA^1$ in relation to the pipe. Extend A^1E and B^1F to intersect in C. Describe the arc of main pipe LM in

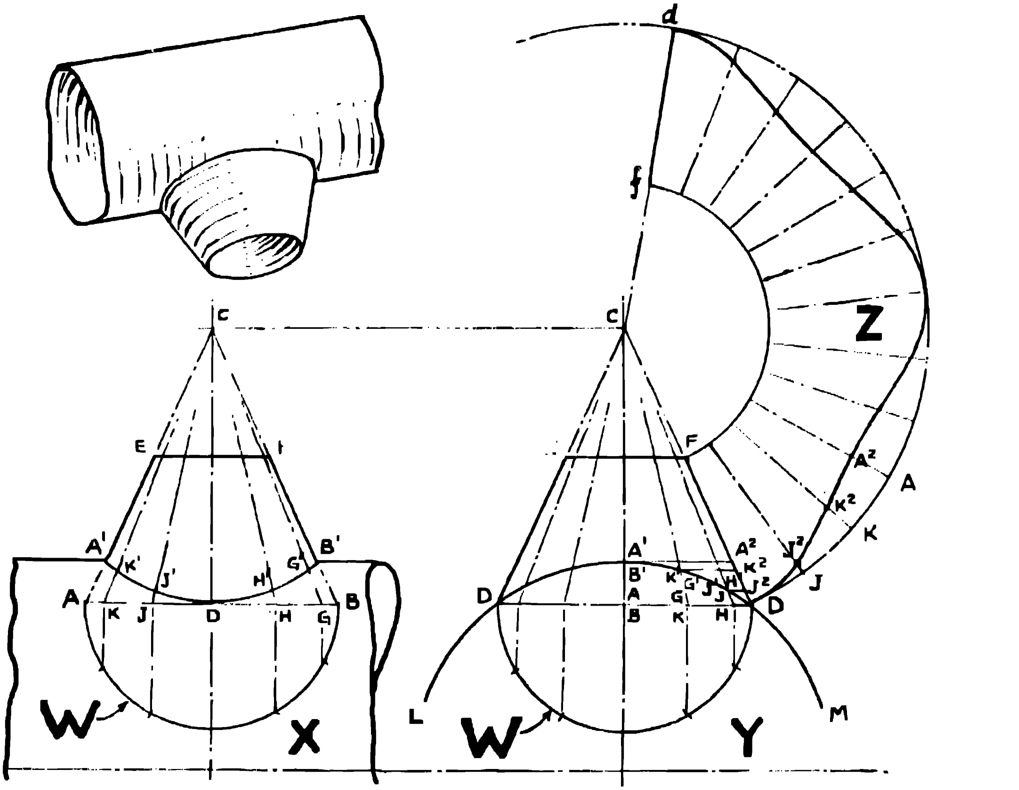


Fig. 260.—Conical branch normal to main pipe.

Fig. Y and add the conical branch. Draw a horizontal line DD, and on this describe a semicircle W, dividing same into six equal parts. Project the division points to line DD and thence by radial lines to the apex C. Project DD horizontally to Fig. X and extend CA^1 and CB^1 to intersect in A and B. Add a semicircle W on AB and divide into six equal parts. Project points perpendicularly to AB, and thence by radial lines to C.

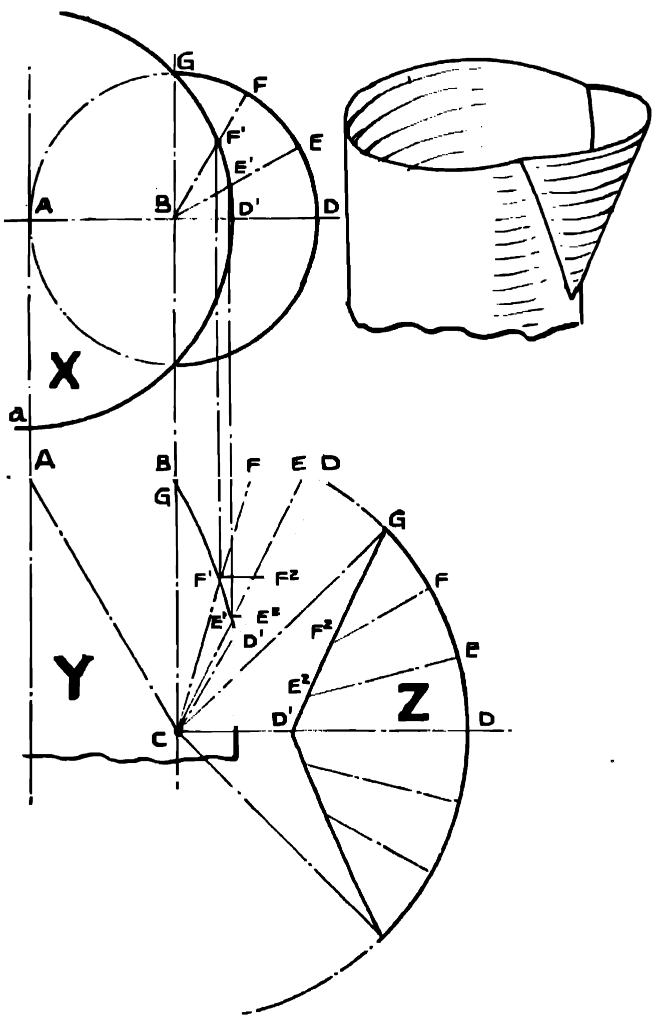


Fig. 261.—Conical-shaped lip on side of cylinder.

To draw the curve A^1B^1 (Fig. X): project points K^1, J^1, D, H^1, and G^1 from Fig. Y to intersect radial lines CK, CJ, CD, etc., in K^1, J^1, D, etc., and draw a curve through points thus found.

To draw the pattern for the branch: set compasses on C as centre, and with CD radius draw an arc D*d* whose length equals the circumference of DD. Divide D*d* into twelve equal parts, and add radial lines as shown, also with centre C describe arc F*f* with radius CF. Project points A^1, K^1, and J^1 horizontally to cut slanting line CD in A^2, K^2, and J^2. Now with centre C and radius CJ^2 cut radial lines CJ in J^2. Repeat with radii CK^2 and CA^2, cutting radial lines CK and CA in K^2 and A^2. A curve drawn through points D, J^2, K^2, and A^2 completes the development of one-quarter of the pattern, and this can be repeated as required.

Conical-shaped Lip on Cylinder (Fig. 261).—First draw Fig X, commencing with centre lines to intersect at A and B. Describe an arc of

A*a* radius to represent the cylinder, and another of BD radius for the lip of same. Divide GD into equal parts and proceed to draw Fig. Y, showing DC at the required angle. Project points F and E perpendicularly from Fig. X and add radial lines to C. Also project points F^1 and E^1 (Fig. X) perpendicularly to cut the radial lines CF and CE in F^1 and E^1 (Fig. Y). Draw a curve through points B, F^1, E^1, and D^1.

To develop the pattern (Fig. Z): draw a horizontal line CD, and with C as centre and CD radius, describe an arc DG on each side. Divide the arc into equal parts and add radial lines CG, CF, and CE. With centre C and radius CF^2 (Fig. Y) cut the radial lines CF (Fig. Z) in F^2. Similarly, with radius CE^2 cut radial lines CE (Fig. Z) in E^2. Finally, with radius CD^1 cut CD in D^1 and a curve GD^1 completes one-half of the pattern. This can be repeated on the bottom half, as shown at Fig. Z.

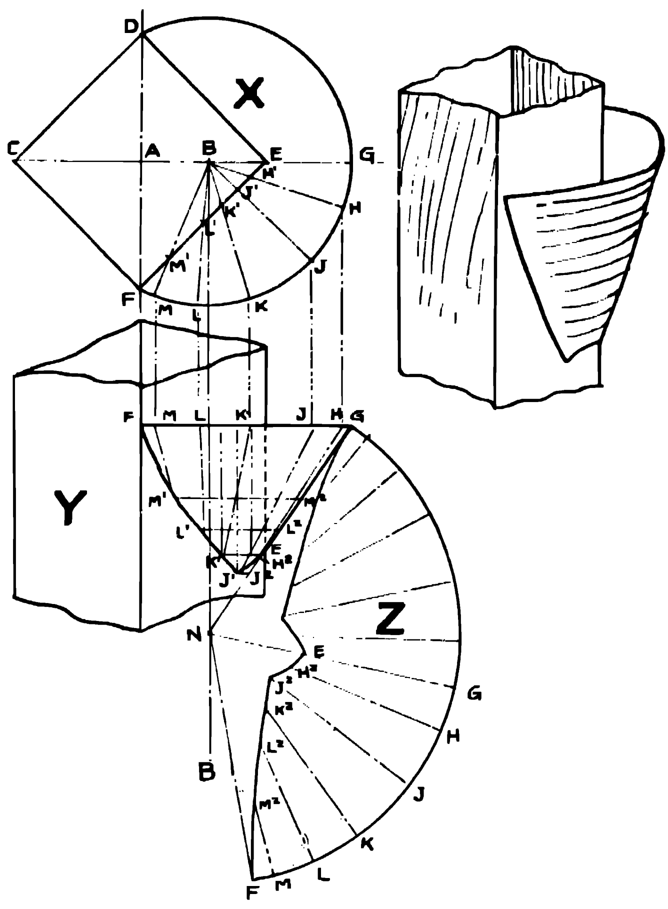


Fig. 262.—Conical-shaped lip on corner of square pipe.

Conical-shaped Lip fitted to Corner of Square Pipe (Fig. 262).—Commence by drawing Fig. X, indicating the square pipe CDEF and lip DGF struck from B as centre. Bisect FE as shown, and add radiating lines BM, BL, BK, BJ, and BH. Now draw Fig. Y, showing GE at the required angle, and producing this line to cut the perpendicular centre line BB in N, the apex of the cone. Next project perpendicularly points M, L, K, S, and H from Fig. X to cut FG in M, L, K, J, and H. Draw radiating lines from latter points to N and project perpendicularly from Fig. X points H^1, J^1, K^1, L^1, and M^1 to cut radiating lines NH, NJ, NK, NL, and NM in H^1, J^1, K^1, L^1, and M^1. Draw curves through these latter points and project same horizontally to cut GN in H^2, J^2, K^2, L^2, and M^2.

To develop the pattern: with N as centre and NG as radius, describe an arc GF whose length equals the circumference of the lip FD. Divide this latter arc up as shown, spacing as in Fig. X. Draw radial lines through points found, and with N as centre and NM^2 as radius cut NM in M^2. Repeat, using NL^2, NK^2, NJ^2, NH^2, and NE as radii and cutting NM, NL, NK, NJ, NH, and NG in M^2, L^2, K^2, J^2, H^2, and E. Draw curves through the latter points to form one-half of the pattern development.

Conical-shaped Object with Circular Base and Circular Branch Set Obliquely at the Apex (Fig. 263).—Commence by drawing the elevation Fig. U in which the object is shown with base of diameter AB and the branch pipe FLMKF in position required.

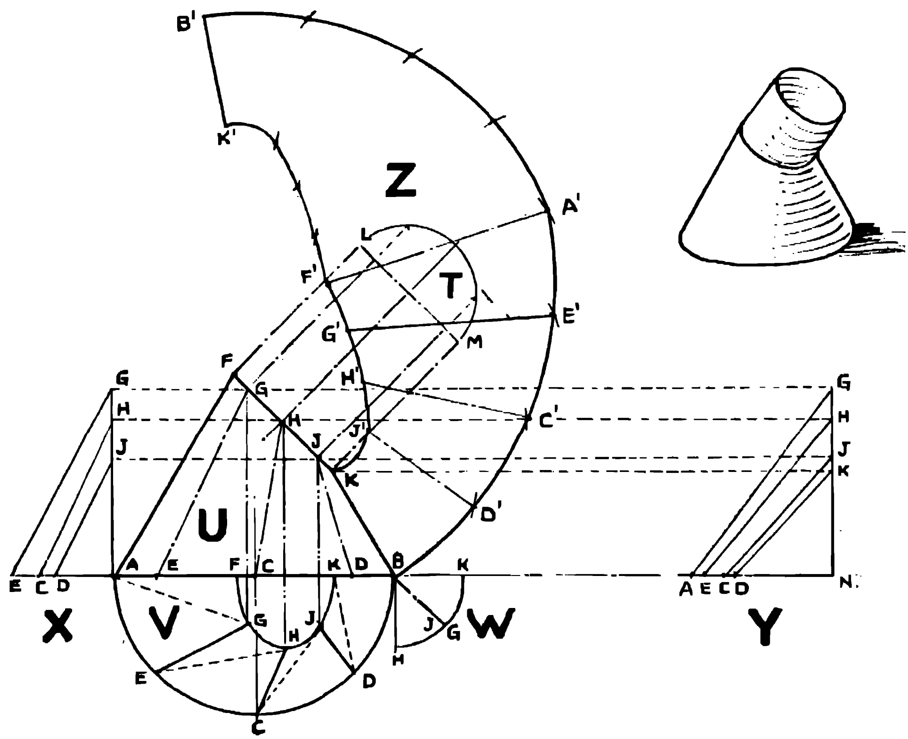


Fig. 263.—Conical-shaped object with circular base and apex.

Describe semicircles T and V on LM and AB. Divide these into equal parts as shown and project points found normal to respective bases to obtain points G and J and E and D. Connect EG, DJ, and CH with lines.

To show the semi-ellipse FHK in Fig. V, project points F and K (Fig. U) perpendicularly to cut AB in F and K. Also project points G, H, and J with lines extended into Fig. V.

Draw with radius FH (Fig. U) a quarter circle W to the right of Fig. V, bisect this, and project points J, G, and H horizontally to cut similarly lettered lines in points J, G, and H (Fig. V). Draw a semi-ellipse through these points and join GE, HC, and JD.

Before going on to draw the pattern, the true lengths of lines GE, HC, and JD must be obtained, also the true lengths for AG, EH, CJ, and DK. The former are obtained from the offset diagram X, and the latter from diagram Y. Diagram X is drawn, commencing with a perpendicular line AG. The heights of points G, H, and J are projected horizontally from Fig. U to this. Horizontal distances AD, AC, and AE correspond with JD, HC, and GE at Fig. V. Join EG, HC, and JD.

The offset diagram (Fig. Y) is also commenced with a perpendicular line and points G, H, J, and K projected as already explained. The horizontal distances ND, NC, NE, and NA correspond with AG, EH, CJ, and DK (Fig. V).

To draw the pattern: take B as centre (Fig. U), and with radius BD (Fig. V) draw an arc at D. Next set compasses to HD (diagram Y), and with K as centre cut existing arc at D^1. Again, with K as centre and radius KJ, describe an arc at J^1. Set compasses to the true length JD (diagram X), and with D^1 as centre describe an arc to cut existing arc in point J^1.

Points C^1, H^1, E^1, G^1, A^1, and F^1 are obtained by the method just described, using the true lengths of lines from X and Y in conjunction with the arc lengths used previously. Draw curves through the points found thus, and duplicate the half pattern by adding the reverse half, $F^1K^1B^1A^1F^1$.

Cone Intersected by Circular Pipe Normal to Side (Fig. 264).—Draw the cone with base AB and vertical height CD, and show the circular branch EFGHE in the required position and normal to CB.

Draw a semicircle AB on the base of cone and add a semicircle on HG.

Divide the semicircle HG into four equal parts and draw lines through L and M parallel to JK. To draw the curve EF we must first obtain the correct position of points L^1, K^1, and M^1 by taking parabolic sections through the cone parallel to JK along lines L^1L, K^1K, and M^1M.

The method of obtaining these sections is explained at Fig. 265, and the projected curves are drawn in the half plan X.

A quarter circle with radius equal to that of the branch pipe is drawn with B as centre, and this is bisected as shown. Lines are now drawn through points P and N parallel to AB to intersect curves Q, R, and S in L^1, K^1, and M^1. A curve drawn through points EL^1, K^1, M^1, and F indicates the shape of the aperture in the side of the cone in plan.

Next draw radial lines through DL^1, DK^1, and DM^1 to cut the semicircle AB in U, T, and V. Project latter points perpendicularly to the base line AB, and thence to the apex C to cut L^1L in L^1, K^1K in K^1, and M^1M in M^1. Draw a curve EF through points thus found. To draw the

development Y of the branch pipe: draw parallel to HG a line HH^1 equal in length to the circumference of the branch pipe. Divide this into eight equal parts as shown.

The lengths of ordinates EH, L^1L, K^1K, etc., are measured from similar ordinates at Fig. W and a curve EE^1 is drawn to complete the pattern EE^1H^1HE.

To draw the development of the cone showing the aperture for the branch pipe: draw the arc BB^1 with centre C and radius CB. Join B^1C and bisect the arc B^1B in B^2, drawing a centre line B^2C. Through points

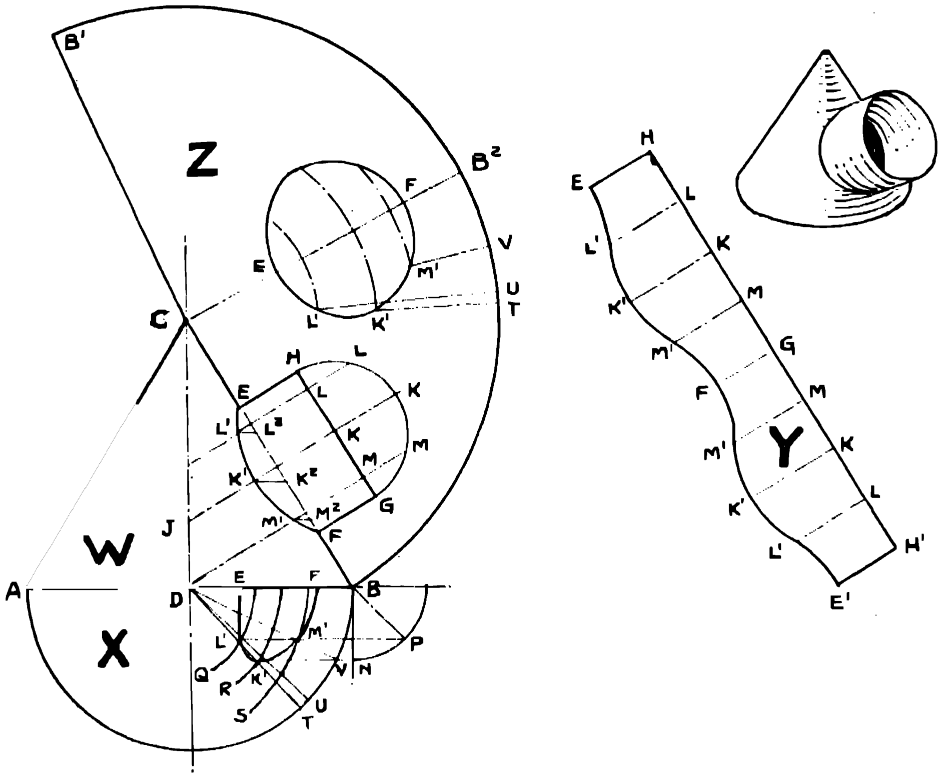


Fig. 264.—Cone penetrated by pipe normal to side.

M^1, K^1, L^1 (Fig. W), draw lines parallel to AB to intersect CB in M^2, K^2, and L^2. Now with centre C and radii CE, CL^2, CK^2, CM^2, and CF, describe arcs across CB^2 (Fig. Z) as shown. Measure lengths of arcs BV, BU, and BT (Fig. X), and set these off from B^2 (Fig. Z) on the arc B^1B.

Through points V, U, and T draw radial lines to C to cut arcs in M^1, L^1, and K^1 as shown. A curve drawn through E, L^1, K^1, M^1, and F should be duplicated to complete the developed aperture (Fig. Z).

Projection of Parabolic Section of Cone (Fig. 265).—Let ABC represent the elevation of a cone cut in parabolic section by a line DE.

To draw the section in plan proceed as follows: divide FE and FD into equal parts as shown. Through points J, H, and G and KL and M draw lines parallel to the base AB; also draw perpendicular lines through these points to extend across AB.

Describe a semicircle on AB. Now set compasses to radii J^1J^1, H^1H^1, G^1G^1, FF^1, K^1K^1, L^1L^1, and M^1M^1, and with N as centre cut similarly lettered perpendicular lines in J, H, G, F, K, L, and M (Fig. Y). A curve drawn through the latter points as shown completes the projection of the parabolic section.

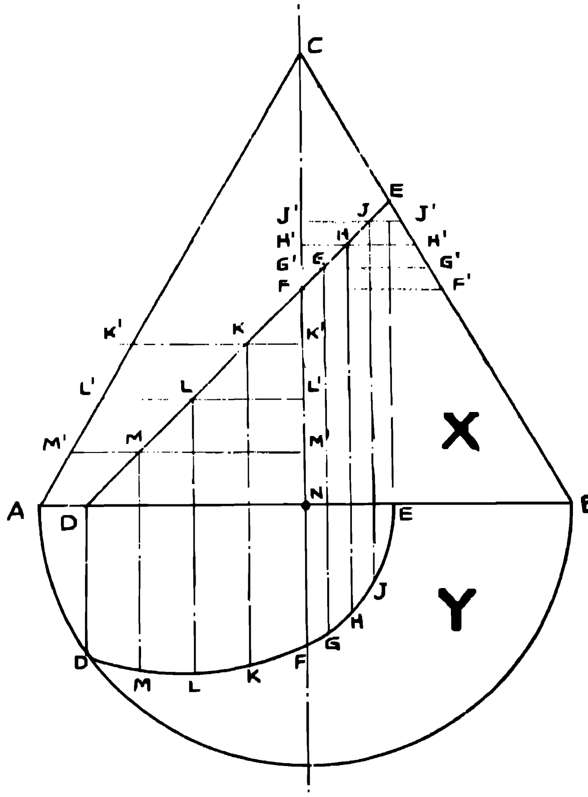


Fig. 265.—Projection of parabolic section of cone.

Cone Pierced by Another Cone Normal to its Side (Fig. 266). Commence by drawing the elevation W, in which the cone ABC is shown pierced by a cone DEF. Describe semicircles on bases AB and DE and divide semicircle DE into four equal parts. Project points G and J parallel to HF to the base DE and thence by radial lines to F.

In order to obtain points G^2, H^2, and J^2, and the curve of intersection (Fig. W), we must take sections through FG^1, FH^1, and FJ^1 and show these as projected curves in the half plan X. (For the method of drawing projected sections of a cone, see Fig. 265.)

The intersecting cone is now shown in the half plan X by projecting points D and E perpendicularly, and also drawing perpendicular lines through points G^1, H^1, and J^1.

The semi-elliptical shape of the projected base DE is indicated by drawing a quarter circle V with radius H^1E and bisecting this as shown. Project horizontally points K and L to intersect previously drawn projection lines in J^1, G^1, and H^1 and draw an elliptical curve through D, G^1, H^1, J^1, and E. Draw radial lines FJ^1, FH^1, and FG^1 to intersect curves 3, 2, and 1 respectively in J^2, H^2, and G^2. A curve drawn

through D^1, G^2, H^2, J^2, and E^1 shows the curve of penetration in the half plan.

To obtain the curve D^1E^1 (Fig. W) project points M, N, and P perpendicularly to the base AB, and thence to the apex C to intersect FJ^1, FH^1, and FG^1 in J^2, H^2, and G^2 respectively. Draw a curve through the latter points to D^1 and E^1. The development of the hole of penetration in the cone ABC is shown in Fig. Y. To draw this, carry horizontal lines through G^2, H^2, and J^2 (Fig. W) to cut CB in G^3, H^3, and J^3. Set compasses to CG^3, CH^3, and CJ^3 as radii and describe arcs 4, 5, and 6 (Fig. Y).

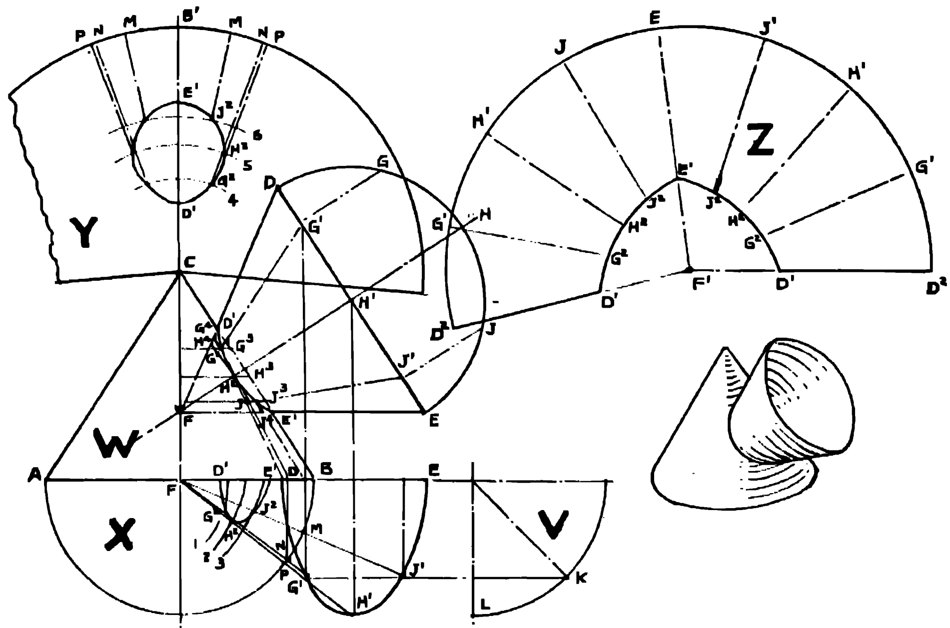


Fig. 266.—Cone penetrated by cone normal to side.

Also set compasses to CB as radius and draw an arc in Fig. Y. Extend the centre line CF perpendicularly to cut the latter arc in B^1.

On each side of B^1 (Fig. Y) set off B^1M, MN, and NP as obtained from the semicircle (Fig. X). Next draw radial lines to C to cut previously drawn arcs 4, 5, and 6 in G^2, H^2, and J^2 as shown. Add a curve through the points found to complete the development of the aperture in the side of cone. To draw the development Z of the cone DEF, commence by drawing with centre F^1 an arc D^2D^2 whose length equals the circumference of the base DE. Divide D^2D^2 into eight equal parts and draw radial lines to F^1. Referring to Fig. W, project points G^2 and H^2 normal to FH^1 to cut FD in G^4 and H^4, also project normal to FH^1 point J^2 to cut FE in J^4. Now measure distances FD^1, FG^4, FH^4, FJ^4, and FE^1 and with F^1 as centre (Fig. Z) set off these distances along radial lines F^1D^2,

F^1G^1, FH^1, F^1J^1, and F^1E to obtain points D^1, G^2, H^2, J^2, and E^1. Draw a curve through latter points to complete the pattern (Fig. Z).

Cone with Another Cone Normal to its Side (Fig. 267).—Draw the elevation W, showing the cone ABC intersected by a cone DEF normal to CB. Describe a semicircle on the base DE and divide same into six equal parts. Project points found parallel to GF to intersect DE in

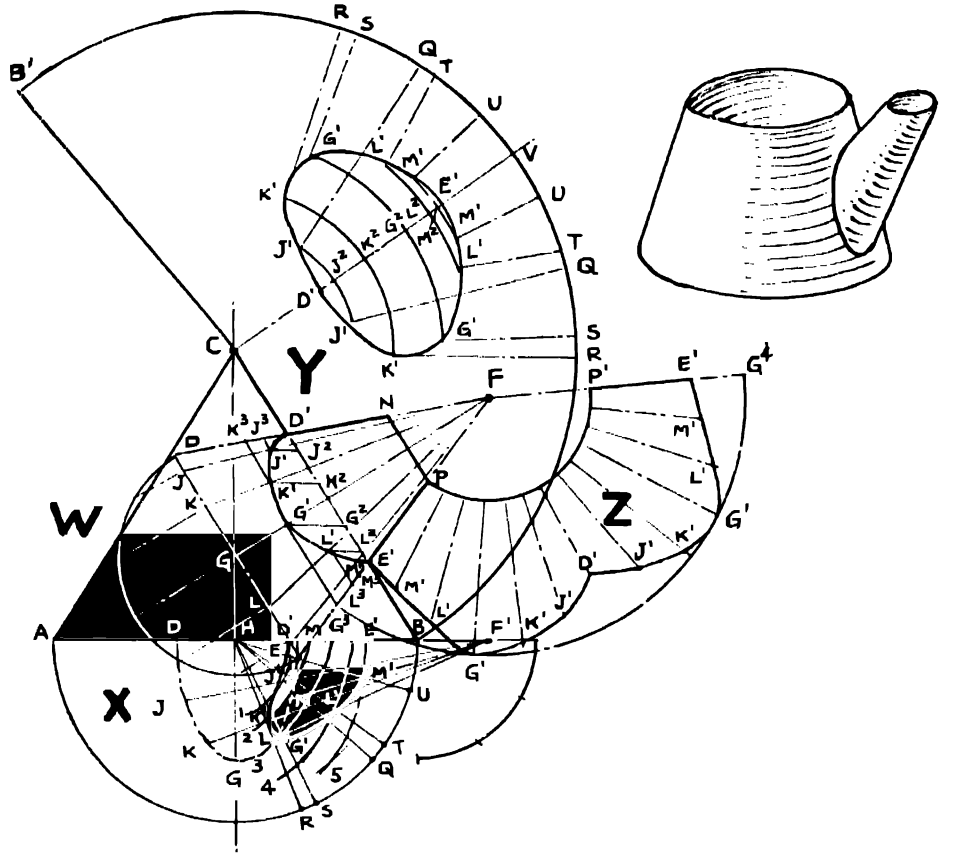


Fig. 267.—Cone penetrated by cone normal to side.

J, K, L, and M. Add radial lines from latter points to F and indicate the position of line NP if required.

To draw the curve D^1E^1: describe a semicircle on the base AB. A series of five projected parabolic sections on planes JF, KF, GF, LF, and MF are now indicated in Fig. X by curves 1, 2, 3, 4, and 5.

The cone DEF is next projected into the half plan X as illustrated, showing the semi-elliptical appearance of the base drawn by projecting perpendicularly points D, J, K, L, M, and E, also by horizontal projec-

tion of points from a quarter circle shown to the right of Fig X. This quarter circle is described with radius equal DG and divided into three equal parts. The points of intersection of perpendicular and horizontal lines indicate the elliptical form of the projected base DE in plan.

Radial lines are now drawn through points J, K, G, L, and M to F^1 to intersect curves 1, 2, 3, 4, and 5 in points J^1, K^1, G^1, L^1, and M^1. Points D^1 and E^1 are projected perpendicularly from Fig. W to the base AB and curves drawn through points D^1, J^1, K^1, G^1, L^1, M^1, and E^1.

To draw the curve D^1E^1 in the elevation Fig. W proceed as follows: Through points J^1, K^1, G^1, L^1, and M^1 (Fig. X) draw lines to radiate from H to the base semicircle AB to cut same in points Q, R, S, T, and U.

Now project the latter points perpendicularly to the base line AB, and thence radially to the apex C to intersect lines JF, KF, GF, LF, and MF in J^1, K^1, G^1, L^1, and M^1. A curve drawn through D, J^1, K^1, G^1, L^1, M^1, and E^1 completes the elevation Fig. W.

To draw the development of the cone ABC: with C as centre and radius CB, describe arc BB^1 whose length equals the circumference of AB. Bisect this arc in V and add a line CV. On each side of V set off VU equal BU (Fig. X), also UT, TQ, QS, and SR, obtaining these distances from Fig. X.

Next, in Fig. W, draw horizontal lines through J^1 ,K^1, G^1, L^1, and M^1 to cut CB in J^2, K^2, G^2, L^2, and M^2. Now set compasses to CD^1, CJ^2, CK^2, CG^2, CL^2, CM^2, and CE^1, and with C as centre, describe arcs across the centre line CV (Fig. Y) as shown. To indicate the form of the hole of penetration, draw radial lines from points R, S, Q, T, and U on the arc B, B^1 to cut the arcs K^2, G^2, J^2, L^2, and M^2 in points K^1, G^1, J^1, L^1, and M^1. A curved line connecting the latter points with D^1 and E^1 completes the development of the hole and incidentally that of the cone ABC.

To develop the pattern for the conical branch D^1, E, F, D^1: in Fig. W project points J^1, K^1, G^1, L^1, and M^1 normal to GF to cut DF in J^3 and K^3 and FE in G^3, L^3, and M^3. With F as centre and FG^3 radius, describe an arc G^3G^4 (Fig. Z) whose circumference equals that of a circle of G^1G^3 radius.

Divide arc G^3G^4 into twelve equal spaces and add radial lines through the points found to F. Now with radii FM^3, FL^3, FG^3, FK^3, FJ^3, and FD^1 and centre F, draw arcs to cut radial lines as shown in Fig. Z in M^1, L^1, G^1, K^1, J^1, and D^1. This completes the development of one-half of the pattern which may be easily duplicated and an arc PP^1 added to indicate the truncation of the cone if required.

Circular Pipe with Conical Branch Out of Centre (Fig. 268).—Fig. X shows an end elevation of the pipe whose radius is DE. The centre of the conical branch is shown to be eccentric by a distance DC. Draw the circle for the pipe and add the cone ABC as required. Describe a semicircle on the base AB and divide this into six equal parts. Project points found perpendicularly to the base AB to obtain points G, H, J, and K.

Add radial lines from these latter points to apex C to cut the circle of the pipe in G^1, H^1, J^1, and K.

To develop the pattern for the cone as shown at Fig. Y: with C as centre and radius CB, describe an arc BB^2 equal in length to the circumference of the base AB. Divide this equally into twelve spaces and letter as shown. Draw radial lines through points on arc BB^2 to C. At Fig. X, draw horizontal lines through points A^1, G^1, H^1, F^1, J^1, and K^1 to cut CB in A^2, G^2, H^2, F^2, J^2, and K^2. Now set compasses on C as centre, and with radii CK^2, CJ^2, CF^2, CH^2, CG^2, and CA^2 draw arcs to cut radial lines CK, CJ, CF, CH, CG, and CA in K^1, J^1, F^1, H^1, G^1, and A^1.

Draw a curve through the latter points to complete the development of the pattern for the branch.

Circular Pipe with Oblique Conical Branch Out of Centre (Fig. 269).—Figs. X and Y illustrate end and front elevations, and it will be seen that the branch DEC is not only eccentric to the circular pipe, but also that it lies at an angle to this. Draw a horizontal centre line, and on this, with A as centre and radius of pipe AB, describe a circle in Fig. X. Set off AC the desired eccentricity of the pipe and conical branch and draw a perpendicular centre line through C.

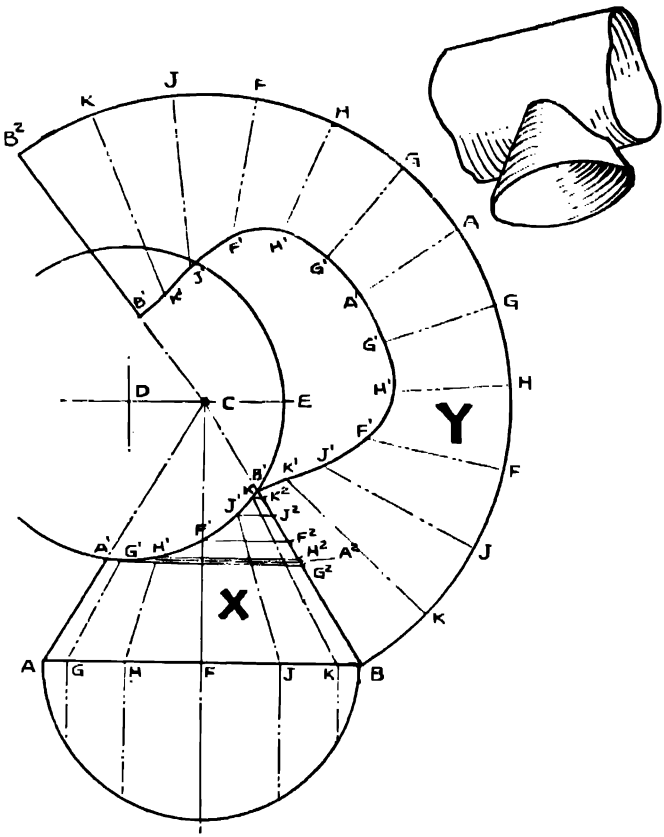


Fig. 268.—Pipe with conical branch out of centre.

Now draw the pipe in Fig. Y, and indicate the conical branch DEC here as shown. With F as centre, describe a semicircle on the base and divide this into six equal parts.

Project points found parallel with CF to cut DE in G, H, J, and K. From these latter points draw radial lines to C.

Now proceed to draw the cone DEC in Fig. X. Commence by project-

ing a line FN from F (Fig. Y) to intersect the perpendicular centre line in R. With R as centre, describe a semicircle with radius FE. Divide this into six equal parts, and draw perpendicular lines through points thus found. Next project horizontally from Fig Y lines from points E, K, L, J, M, F, N, H, P, G, Q, and D to cut the perpendicular lines just drawn at Fig X in points E, K, L, J, M, etc., as shown. Complete the ellipse by adding a curve through the latter points, and draw radial lines through these points to C.

Now project points J^1, F^1, H^1, G^1, E^1, etc., from Fig. X to cut similarly lettered radial lines in Fig. Y in points J^1, F^1, H^1, etc.

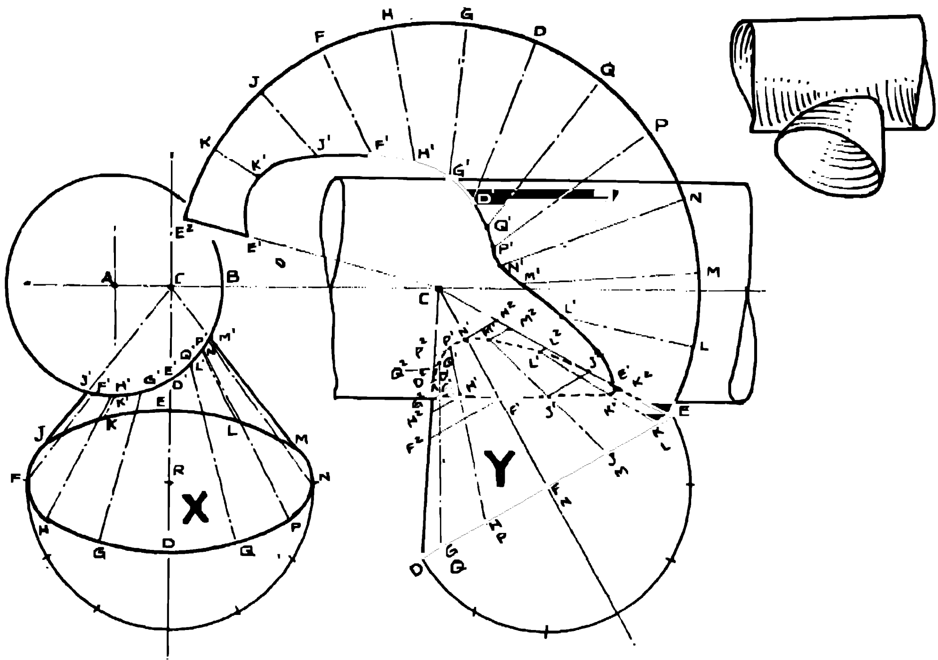


Fig. 269. Pipe with oblique conical branch.

Draw a curve through the latter points and project those parallel to DE to cut CD in F^2, H^2, G^2, D^2, Q^2, and P^2, also cutting CE in N^2, M^2, L^2, J^2, and K^2.

To develop the pattern for the conical branch CDE proceed as follows: with centre C and radius CE, describe an arc EE^2 whose length equals the circumference of base DE. Divide this into twelve equal parts, and add radial lines to C through points thus found.

Now set compasses on C as centre, and with CL^2, CM^2, CN^2, CP^2, CQ^2, CD^2, etc., as radii cut radial lines CL, CM, CN, CP, CQ, etc., in L^1, M^1, N^1, P^1, Q^1, etc.

Draw a curve through these latter points to complete the pattern as shown.

Truncated Cone with Oval Base (Fig. 270).—This is an unusual type of cone, but it has its application, as shown in the small sketch, where a large pipe is cut in elliptical section and joined to a smaller pipe at right angles by an elliptical cone frustum.

Draw the elevation W in which CB is the length of the major axis of the cone base, AG the perpendicular height of the whole cone, and Gg the height of the cone frustum. Next add a half plan X. Divide the half ellipse CB up as required and draw radial lines to G.

Now draw the offset diagram Fig. Y, commencing with an extension of CB. Erect on this a perpendicular line LM, making this equal AG. Measure the distances GB, GD, GE, GF, and GG, and set off these distances horizontally in Fig. Y as shown. Add radial lines through points B, D, E, F, and G to L and project line *cb* from Fig. W to Fig. Y.

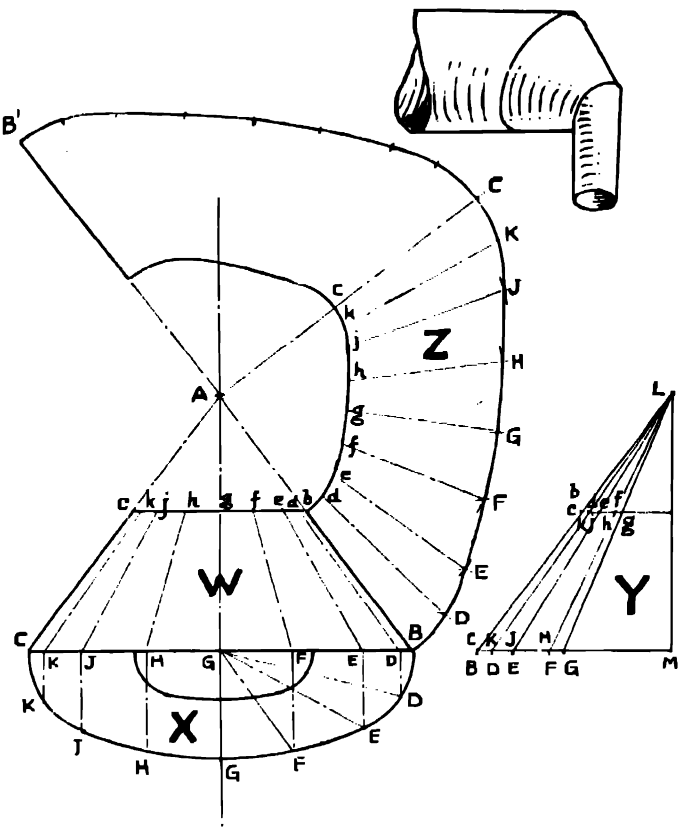


Fig. 270.—Truncated cone with oval base.

To draw the development of the pattern Z, set compasses to the distance BD (Fig. X), and with B as centre, draw an arc at D to be cut by an arc of LD radius struck from A as centre. Next set compasses to DE (Fig. X), and with D (Fig. X) as centre draw an arc at E to be cut by an arc of LE radius, struck from A. Repeat with radii EF and LF, FG and LG, etc., to complete the development of the half-base curve CB. The curve *bc* is drawn by setting off distances L*d*, L*e*, L*f*, etc., along the radial lines AD, AE, AF, etc., with A as centre.

Conical End Cap to join Large and Small Pipes at Right Angles (Fig. 271).—It has been shown in previous examples that a cylinder cut at an angle to its axis is elliptical in section. The same can be said of a

true cone, which is cut at an angle, as seen at Fig. X. In this case, a circular pipe is shown joined to the cone at right angles, and the ellipse due to the section of the cone agrees with that of the pipe. It is possible to place the pipe too near in relation to the apex of the cone, and to ensure that this does not happen, the position of the horizontal axis will be found by drawing a circle equal to the diameter of the branch pipe inside the cone so that the sides are tangential to same (see dotted circle).

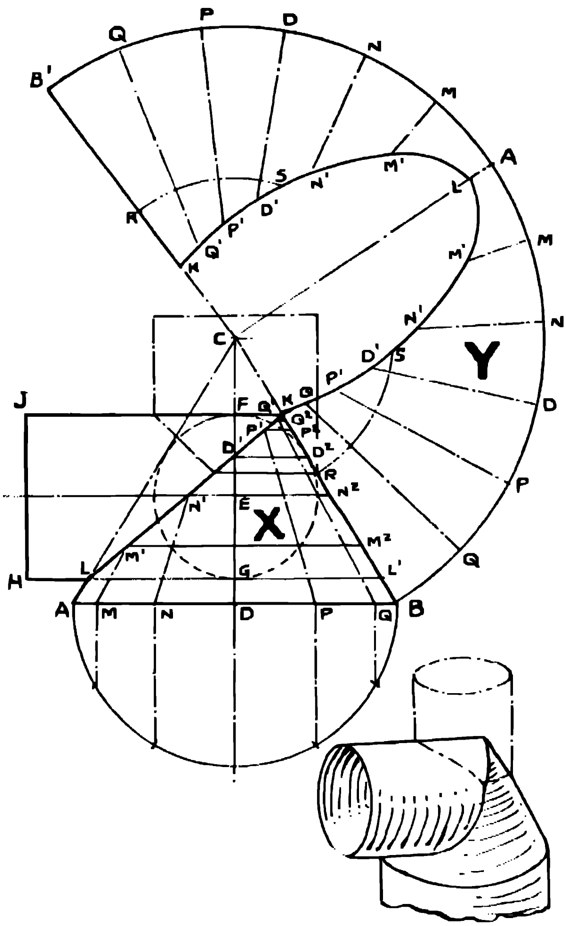


Fig. 271.—Conical end cap joining pipes at right angles.

Draw the cone ABC in elevation as shown at Fig. X; then set compasses to the radius of the branch pipe, and by experiment find the position of the centre E by drawing a circle of EF radius inside the cone.

Tangential to the top and bottom of the circle draw lines JK and GH to intersect the sides of the cone in L and K. Join LK with a line, and with D as centre describe a semicircle on the base AB. Divide this into six equal parts as shown and project points as found perpendicularly to the base line AB, and thence radially to C to cut the diagonal line LK in M^1, N^1, D^1, P^1, and Q^1. Project these latter points horizontally to cut the sides of the cone CB in L^1, M^2, N^2, D^2, P^2, and Q^2.

To develop the pattern Y for the cone: with C as centre and CB radius, describe an arc BB^1 whose length equals that of the cone base AB. Divide arc BB^1 into twelve equal parts, then place compasses on C as centre, and with radii CQ^2, CP^2, CD^2, CN^2, CM^2, and CL^1, cut radial lines CQ, CP, CD, etc., in Q^1, P^1, D^1, N^1, M^1, and L.

The effect on the pattern of the addition of a pipe on the apex of the cone is shown by the dotted arcs RS drawn from C as centre.

Penetration of Cone by a Circular Offset Branch (Fig. 272).—Draw the elevation of the cone ABC, and with E as centre, indicate the diameter

and position of the circle of the branch pipe. Divide the circle into four equal parts and draw radial lines through the numbered points as shown. Re-number at the base AB.

Now, with D as centre, describe a semicircle in Fig. X on the base AB. Project points 1 to 8 from AB perpendicularly to cut the semicircle AB in similarly numbered points. Through these latter points draw radial lines to D, then project perpendicularly numbered points on the circle (Fig. W) to cut similarly numbered radial lines in the half plan (Fig. X).

Lines should be dropped from points 7 and 3 to indicate the length of the branch pipe, and a curve drawn through the numbered points to show the projection of the hole of penetration in the plan.

To develop the branch shown at Fig. Y, extend FG, making GG equal the circumference of the branch pipe. Divide this length into eight equal parts and erect perpendiculars through points thus obtained, numbering the lines as shown. Now project horizontally similarly numbered points from the hole in Fig. X to cut numbered lines in Fig. Y. A curve drawn through these latter points completes the pattern.

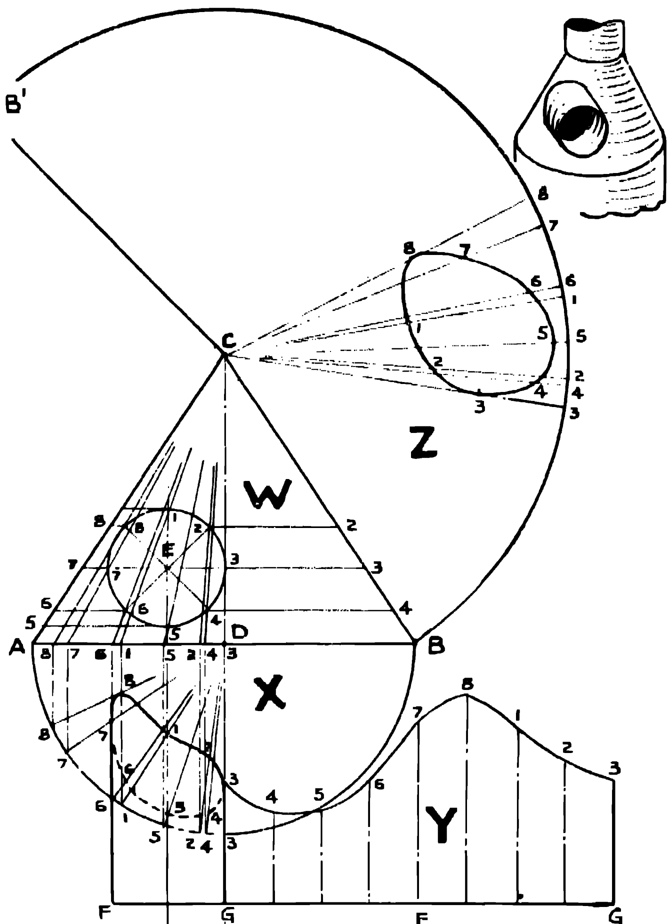


Fig. 272.—Penetration of cone by circular branch pipe.

To draw the development of the cone (Fig. Z): with C as centre and radius CB, describe an arc BB¹ equal in length to the circumference of AB.

Bisect the arc BB¹ in point 8, and draw a line to C through this. Now measure arc lengths 8 to 7, 7 to 6, 6 to 1, etc., as seen at Fig. X, and set these distances off on the arc BB¹ from point 8 as shown.

Draw radial lines through these points to C. Referring back to Fig. W, project horizontally the numbered points on the circle to cut the sides of the cone in similarly numbered points.

Now, with C as centre and radii C^1, C^2, C^3, etc., cut similarly numbered radial lines in Fig. Z and draw a curve through the points of intersection to indicate the shape of the hole of penetration in the pattern.

Cone Penetrated by Square Offset Branch Pipe (Fig. 273).—Fig. V shows the elevation of a cone ABC with a square branch pipe EFGH in position.

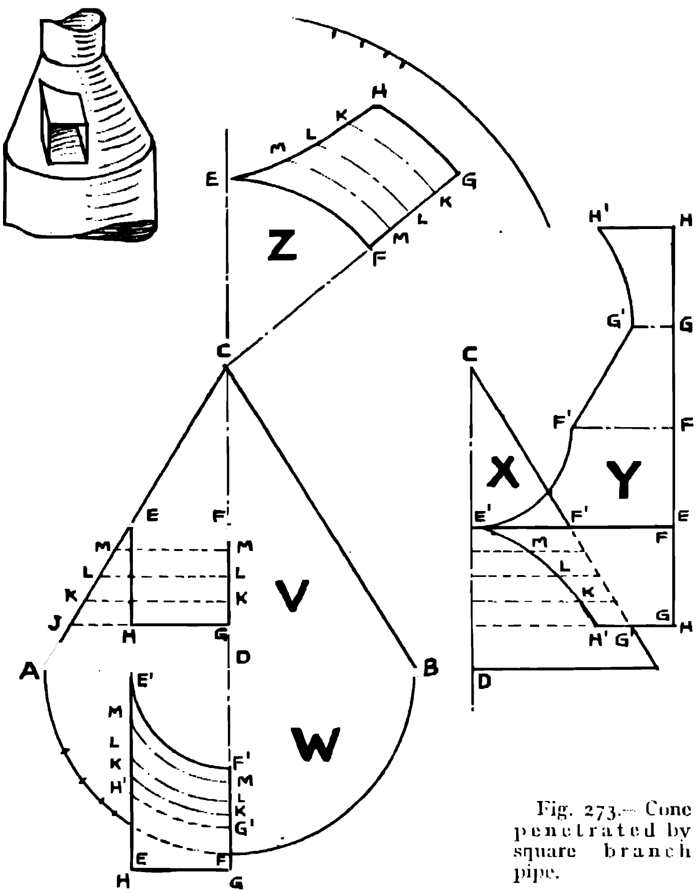


Fig. 273.—Cone penetrated by square branch pipe.

Draw a half plan (Fig. W) describing a semicircle on the base AB. Project EH and FG perpendicularly from Fig. W to Fig. X to indicate the branch in plan. At Fig. X is seen a half-end elevation, the branch being projected from Fig. V. The curve E^1H^1 is a hyperbolic curve, the method of drawing this was explained at Fig. 32 (Vol. I), but it can be obtained as follows:

Divide EH (Fig. V) into equal parts and draw lines MM, LL, KK, and JG. Set compasses to FE, MM, LL, KK, and JG, and draw arcs in Fig. W. Project lines MM, LL, and KK from Fig. V to Fig. X, and measuring distances E^1M, E^1L, E^1K, and E^1H^1, set off these normal to CD (Fig. X) along similarly lettered lines. Draw a curve through E^1, M, L, K, and H^1 (Fig. X).

To develop the pattern for the branch pipe: parallel to E^1E, draw lines F^1F, G^1G, and H^1H, making the distances EF, FG, and GH equal those measured at Fig. V.

To obtain points F^1, G^1, and H^1, project these points perpendicularly from similarly lettered points in Fig. X. The arc E^1F^1 is a quarter circle

of EF radius, the line F^1G^1 is a straight line, and G^1H^1 is an arc of radius JG. The pattern for the branch is enclosed by H, H^1, E^1, F^1, G^1, H^1, H, H. The development of the hole of penetration is shown at Fig. Z and drawn as follows: set compasses on C as centre, and with CE (Fig. V) radius, draw an arc EF equal in length to E^1F^1 (Fig. W). Also with CJ radius, describe an arc HG at Fig. Z.

Draw a radial line through G to C and make HG equal H^1G^1 (Fig. W). The curve EH is obtained thus: place compasses on C as centre, and with CM, CL, and CK radii, draw arcs MM, LL, and KK in Fig. Z, make the lengths of the latter arcs equal that of similarly lettered arcs in Fig. W and draw the curve EH.

Fitting Pipe at any Angle at the Apex of a Cone (Fig. 274).—In order that a pipe of given diameter can be fitted at the apex of any cone, it is essential that the exact position be obtained relative to the apex.

Draw the cone ABC, and setting compasses to the radius of the branch pipe, describe a circle inside the cone so that the sides of the cone are tangential and the centre is located at D.

The top and bottom lines of the branch pipe GE and FH respectively are now drawn tangential to the circle and GH connected by a line. The sections of the pipe and cone at GH are corresponding ellipses.

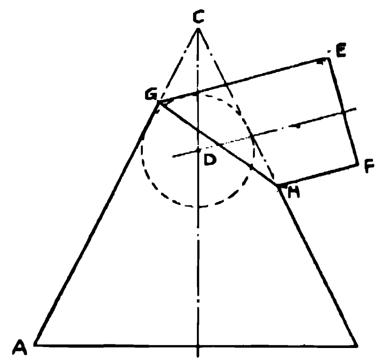


Fig. 274.—Fitting pipe at apex of cone.

Elliptical Section of a Cylinder (Fig. 275).—When a cylinder is cut obliquely, the section is elliptical in form.

To draw the section and development of such a cylinder proceed as follows:

Draw the elevation V of the cylinder ABDC, showing the line CD at the required angle.

Now describe a semicircle W on the base AB. Divide this into six equal parts and project points thus obtained perpendicularly to the line CD, cutting the base line AB in K, J, F, H, and G, also CD in L, M, E, N, and P. Normal to CD project lines through the latter points.

Now draw a quarter circle Y with radius FB and divide this into three equal parts and letter the points as shown. Project the points thus obtained on the circumference parallel with CD to intersect similarly lettered lines at Fig. X in points L^1, M^1, E^1, N^1, and P^1. A curve drawn through C, L^1, M^1, E^1, N^1, P^1, and D indicates the semi-elliptical section of the cylinder at CD.

To draw the development of the cylinder: extend AB to make BB^1 equal the circumference of AB. Divide BB^1 into twelve equal parts and erect perpendicular lines through points thus obtained.

Letter points as shown, and proceed to project horizontally points P, N, E, M, L, and C to intersect the perpendicular lines just drawn at

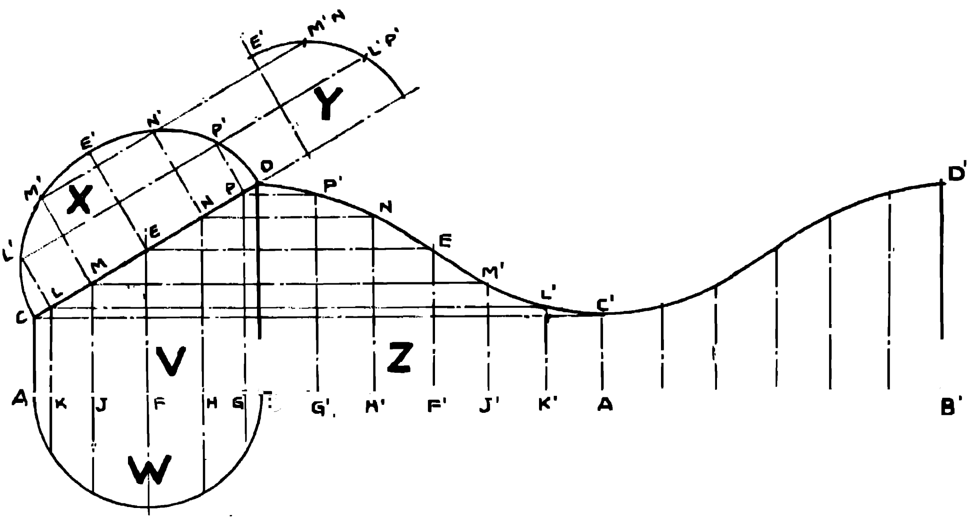


Fig. 275.—Elliptical section of cylinder.

Fig. Z in P^1, N^1, E^1, M^1, L^1, and C^1, and draw a curve through these points. This completes one-half of the development; the other half is an exact reverse of this.

Drawing off a Pipe in Elliptical Section and Method of Forming a Right-angle Bend (Fig. 276).—A practical method by which a pipe may be drawn off for an oblique cut is illustrated at Fig. X, in which it will be seen that the pipe is supported at the required angle and scribed by the use of a surface gauge. By this means a saving of time may be effected. It will be noticed that, if the pipe is cut at the angle of 45 degrees, the two halves, having equal elliptical sections, can be turned at right angles, as shown at Fig. Y, to form a 90-degree bend.

Bend Built Up from Pipe Sections (Fig. 277).—Fig. X shows a form of pipe bend which can be easily produced with the aid of a cutting and welding plant. The bend is seen to consist of three full sections B, C, and D and two half-sections A and E.

Fig. Y shows how the sections can be drawn off on a straight length of pipe, and it will be appreciated that, by cutting the pipe along the various lines and twisting each section round half a turn in relation to its neighbour, a bend may be assembled, as shown at Fig. X. To design such a bend, draw two centre lines MK and ML at right angles. Next draw the mean radius arc LK as required, later adding arcs FH and JG, making HJ and FG equal the pipe diameter and the angle between lines 90 degrees. Decide next upon the number of full sections to be inserted in the bend, then the angle for cutting the section will be equal to $\frac{90}{(\text{number} \times 2) + 2}$.
Divide the arc LK into the required number of spaces, and draw radial lines through points obtained to N. Add lines for each section tangential

to arcs FH and JG. The pipe may next be drawn off, as seen at Fig. Y, making allowance for cutting at each section line.

Tapered Bend in Three Pieces (Sectioned Radially) (Fig. 278).—This type of bend is usually formed of hollowed sections, and the patterns for these are approximated and obtained as follows:

Draw the elevation of the bend as shown at Fig. X, commencing with centre lines AB and C at right angles, then add the large and small diameter end lines HG and EF.

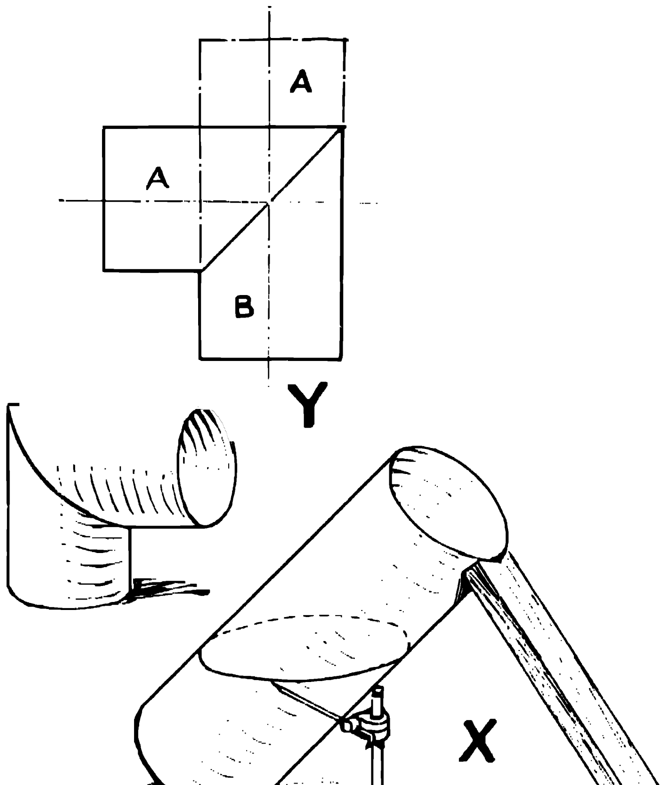


Fig. 276.—Drawing off pipe in elliptical section.

Draw suitable curves EH and FG. Extend HG and EF to intersect at O, then proceed to divide the curve EH into three equal parts (or as many as required). Draw radial lines MO and JO. Connect points HJ, JM, ME, FL, LK, and KG. Bisect HJ, JM, and ME, and add radial lines RO, SO, and TO.

Next describe semicircles on UV, WX, and YZ. Divide the semicircle UV into six equal parts and project points obtained normal to UV to cut same in *a*, *b*, *c*, *d*, and *e*. Also divide the other semicircles WX and YZ into six equal parts and project points normal to their bases to obtain points *f*, *g*, *h*, *j*, and *k*, also *l*, *m*, *n*, *p*, and *q* as shown. Draw lines through latter lettered points parallel to JH, MJ, and ME.

To develop the half pattern of sections commencing with Q: draw a centre line U^1V^1 equal in length to the circumference of semicircle UV (Fig. X). Divide this into six equal parts, and letter as shown. Draw J^1H^1 equal to JH, and at the same angle to U^1V^1, also draw lines a^1, b^1, c^1, d^1, *e*, and V^1 parallel to this and the lengths of these lines equal to

similarly lettered lines at Fig. X. Draw curves J^1F^1 and H^1L^1 to complete this section of the bend.

The development of sections P and M is carried out in the same manner as just described for section Q, but making use of the various lines having application to respective sections.

Note the patterns thus obtained are only half patterns, the other halves are exact duplicates with pattern reversed.

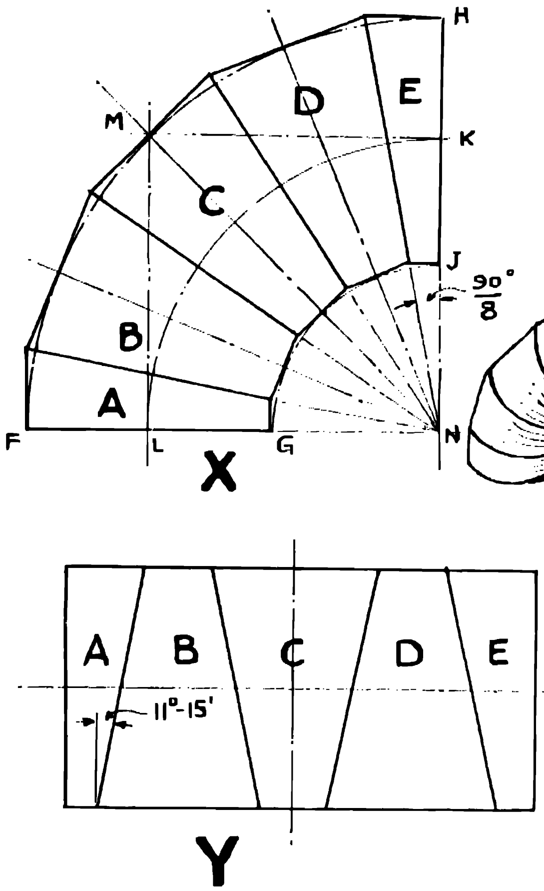
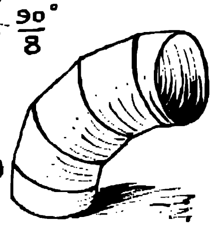


Fig. 277.—Bend built up from pipe sections.



Sections thus formed are hollowed to templates and welded together in assembly.

Tapered Bend Formed with Longitudinal Sections (in four pieces) (Fig. 279).—This is a method of construction still in favour among marine sheet-metal workers. Fig. X shows an elevation of the bend with the small-end diameter AB and large-end diameter CD. The curves AD and BC are drawn as required, and lines AB and CD produced to intersect in O.

The curve AD is next divided equally at F and E, and radial lines drawn to O, cutting the arc BC in H and G. Now describe semicircles on DC, EG, FH, and AB, and divide each into four equal spaces. Project points thus obtained normal to their respective base lines to obtain points NMV, PLU, QKT, and RJS. Draw curves through points NPQR, VUTS, and MLKJ as shown at Fig. X.

Develop patterns for sections A, B, and C as follows: commencing with the pattern for A, draw horizontal and vertical centre lines to intersect in O. Set off along these lines OJ and OM as measured at Fig. X. Repeat the curve JM accurately, setting off points K and L on this. Draw radial lines through K and L to O.

Now set off JR and JS equal one-quarter of the circumference of the semicircle AB (Fig. X). Next mark KQ and KT each equal one-quarter of the circumference of the semicircle FH. Repeat to obtain points P and U and N and V, making use of semicircles EG and DC. Connect NV and RS and draw curves through points KQPN and STUV.

The method of obtaining patterns B and C are somewhat different. To draw pattern B: bisect the arc FE (Fig. X) in W and draw a line through this normal to FE, cutting the curve QP in Y also bisect curve QP in X.

Commence the drawing of pattern with a perpendicular centre line. On this line mark a point W. Draw a horizontal line through this, mak-

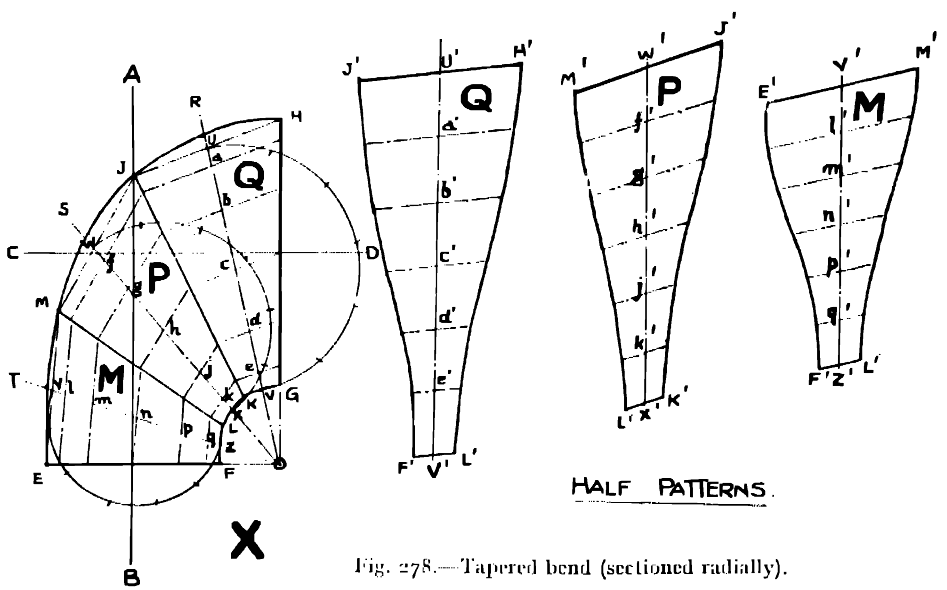


Fig. 278.—Tapered bend (sectioned radially).

ing YY equal the mean length of half the semicircles EG and FH. Set off on the perpendicular line distances WE, WF, ED, and FA, taking these distances from Fig. X. Now measure XY (Fig. X) and mark this distance in Fig. B by a line XX. Next mark off distances XP and XQ, making PP and QQ equal half the circumference of semicircles EG and PH. Again referring to Fig. X measure PN and QR and set off at Fig. B, making NN and RR half the circumference of semicircles DC and AB. Draw curves NDN, RAR, and RN.

Fig. C shows the half pattern for section C. To draw this again refer to Fig. X and bisecting the curve HG in W draw a line through this normal to HG; to cut curve TU in *y* also bisect TU in *x*.

To draw pattern C, commence with a perpendicular centre line. Mark a point *w* and draw a horizontal line *wy* through it, also points G, H, C, and B, taking distances from Fig. X. Now measure *xy* (Fig. X) and set this off in Fig. C. Draw a horizontal line *xx*. Set off on either side of *x*

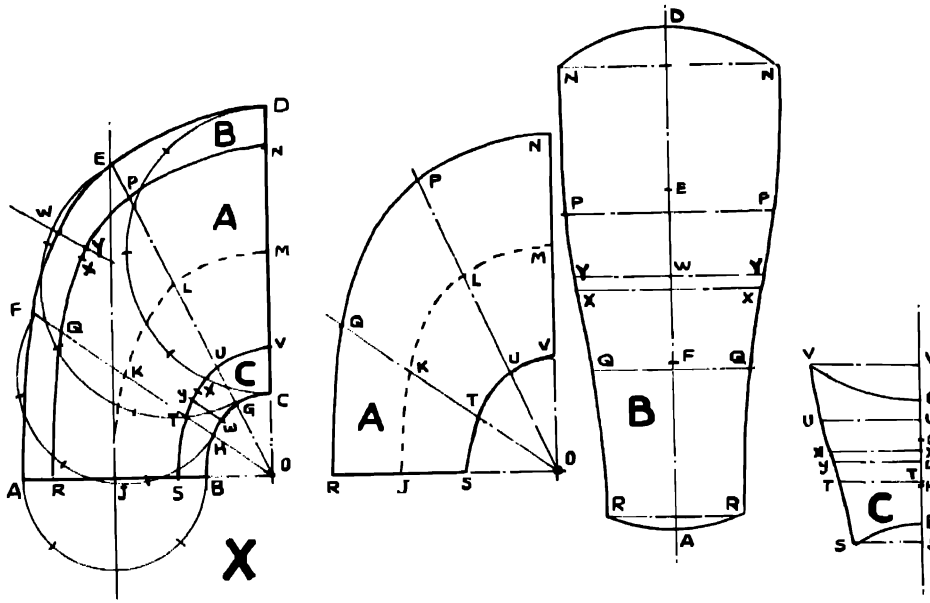


Fig. 279.—Tapered bend formed by longitudinal pieces.

distances xT, xU, Uv, and TS, making TT, UU, VV, and SS equal one-quarter of the circumference of semicircles FH, EG, BC, and AB. Draw curves VC, SB, and VS to complete the drawing of the half pattern.

Y Branch composed of Two Oblique Conical Frusta (Fig. 280).—As previously explained, the base and any horizontal section of an oblique cone is circular. It follows from this that if two similar oblique cones are cut perpendicularly through the centres of their respective bases the vertical sections are bound to be similar, and when placed together as shown at Fig. W the base of the pair will be circular.

To draw the elevation Fig. W: commence with a perpendicular centre line. On this mark a point H, and through this draw a horizontal line, also add centre lines JH and KH for cones at the required angle to the base. Mark off the diameter of the base AB, also diameters EF and CD, at the correct elevation. Draw lines through AE to J, and BD to K, also add lines JG and KG as shown. Now describe a semicircle on the base AB. Divide this up into four equal parts. Drop a perpendicular line from K to Q on an extension of the base line AB. Now with Q as centre and radii QL, QP, and QM cut the base AB in L^1, P^1, and M^1. Add lines L^1K, P^1K, and M^1K.

Perpendicular to L on the semicircle AB draw a line to cut AB in N^1. Add a radial line NK to intersect GH in N^2.

Fig. Z illustrates an end elevation of the frustum showing the form of section GH.

To develop the pattern as shown at Fig. Y, commence with a centre

line KA. With A as centre and AL radius (see Fig. X) describe an arc at L^1 to be cut by an arc of KL^1 radius struck from K. Describe arcs KP^1, KM^1, and KB to be cut in P^1, M^1, and B by arcs of AL radius struck from L^1, P^1, and M^1. Draw lines L^1K, P^1K, M^1K, and BK and add a curve BB. Next measure KG (Fig. W) and set this off in Fig. Y. Also measure KN^2 and mark off along lines KL^1. Draw a curve through P^1N^2G as shown. Now set compasses to KD, KT, KS, KR, and KC and with K as centre (Fig. Y) mark these distances off along KB, KM^1, KP^1, KL^1, and KA, drawing a curve through points thus obtained to complete the pattern.

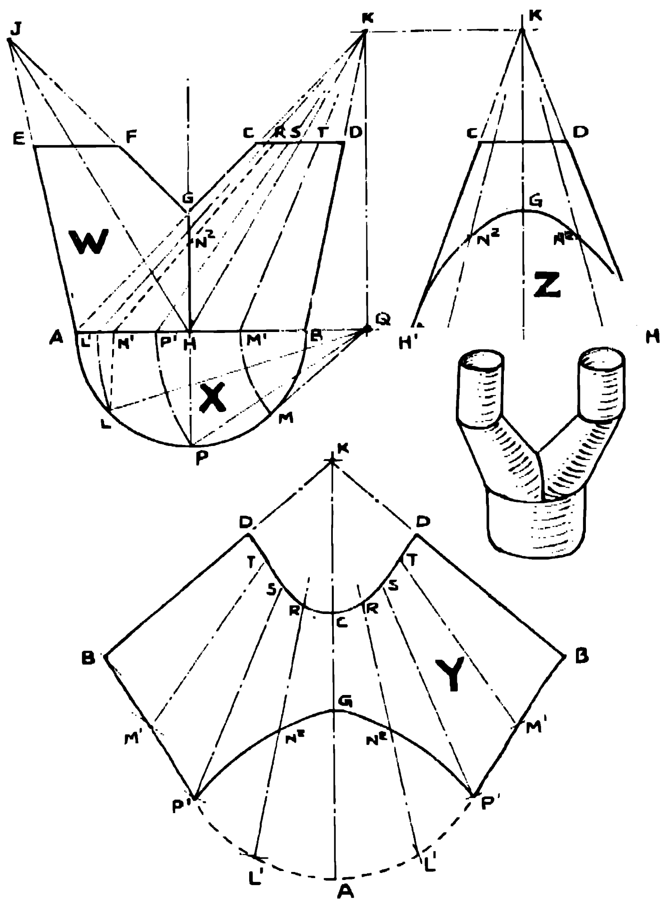


Fig. 280.—Y branch composed of two oblique conical frusta.

Tapered Hopper with Unequal Taper and Rounded Corners (Fig. 281).—Fig. W illustrates the front elevation of the object and Fig. X the end elevation. In the plan view (Fig. Y) it will be seen that the two right-hand corners are formed with unequal radii at top and bottom. By drawing circles at top and bottom and tangential lines as shown, it will be seen that the corners consist of portions of oblique cones. This knowledge is of assistance when developing the object. Draw views W, X, and Y.

In the elevation W set off on CD a distance ED equal to the radius of the corner at the top. Produce DB to intersect an extension of CA in G. Add a line GE. FB will be the radius for the bottom corner (see Fig. Y). With radius ED describe a quarter circle at Fig. W. Divide this into two equal spaces, and with C as centre and with CL, CM, and CN radii cut CD in L, M, and N. Draw radial lines through these points to G.

To develop the half pattern Fig. Z: draw perpendicular and hori-

zontal lines CA, CE, and AF. Through EF draw EG equal to GL (Fig. W) and with G as centre describe arcs of radii GM, GN, and GD approximately at M, N, and D. Now set compasses to radius LM on the arc LD (Fig. W) and with L as centre (Fig. Z) describe an arc to cut the previously drawn arc at M. Repeat, using the same radius successively on M and N to obtain the correct position of these points.

Now set compasses to GP, GQ, GR, and GB (Fig. W) and cut radial lines GL, GM, GN, and GD in P, Q, R, and B. Draw radial lines DG, NG, and MG. Parallel to BD indicate KJ at a distance JD. Normal to CA (Fig. X) and through H draw a line to CA in S. Now in Fig. Z set off CS on CA and draw a horizontal line through S, then with C as centre and radius CH (see Fig. X) cut the horizontal line SH in H. Next with A as centre and radius AH¹ (Fig. X) describe an arc approximately at H¹ to be cut by an arc of radius HH¹ struck from H as centre. Join CH, HH¹, and H¹A and draw curves ED and FB to complete the half pattern.

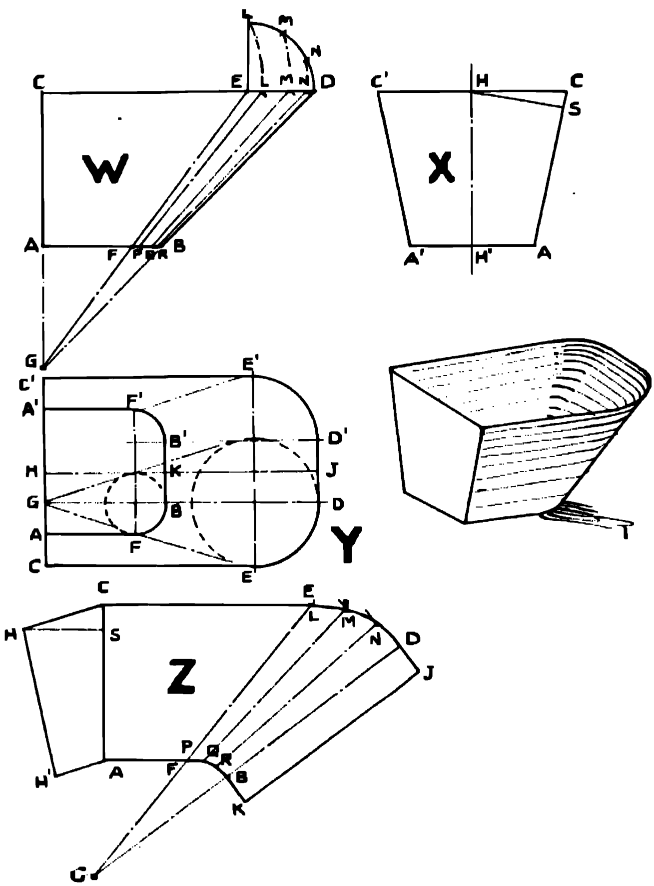


Fig. 281.—Tapered hopper with unequal taper.

Fishtail Spout. Round to Rectangular (in two pieces) (Fig. 282).—This is another example which is composed of oblique conical and flat surfaces.

Fig. W shows the front elevation of the spout with base AB and circular top of CD diameter.

Fig. Y illustrates an end elevation and Fig. X a half plan.

To develop the spout make the following additions to the foregoing views. At Fig. W describe a semicircle on CD. Divide one-half of this into four equal parts, numbering as shown. Extend CD and erect a perpendicular on B to cut this in G.

Now with G as centre and G1, G2, G3, and G4 radii describe arcs to cut CD in points 1, 2, 3, and 4. Join B^1, B^2, B^3, and B^4. The lengths now represent the true lengths of similar lines shown in the plan (Fig. X.)

To draw the half pattern: draw a horizontal line AB, bisect this in F, and draw a centre line perpendicular to this. Now set compasses to B1 (Fig. W) and with A and B as centres describe arcs to intersect in E. Join AE and BE. Next set compasses to B2, B3, B4, and B5 and with B as centre describe arcs near points 2, 3, 4, and 5 (Fig. Z). With radius E2, Fig. X, set compasses on E as centre and cut the arc previously drawn at point number 2. Keep compasses set and with 2 as centre cut arcs at 3, 4, and 5. Join BD and draw the curve ED, repeating same in reverse at CE.

Now with B and A as centres and BB^1 radius (see Fig. X) draw arcs at B^1 and A^1 to be cut by arcs of BD radius (Fig. W) in B^1 and A^1.

Add lines B^1D, CA^1, A^1A, and BB^1 to complete the development of the half pattern for the spout.

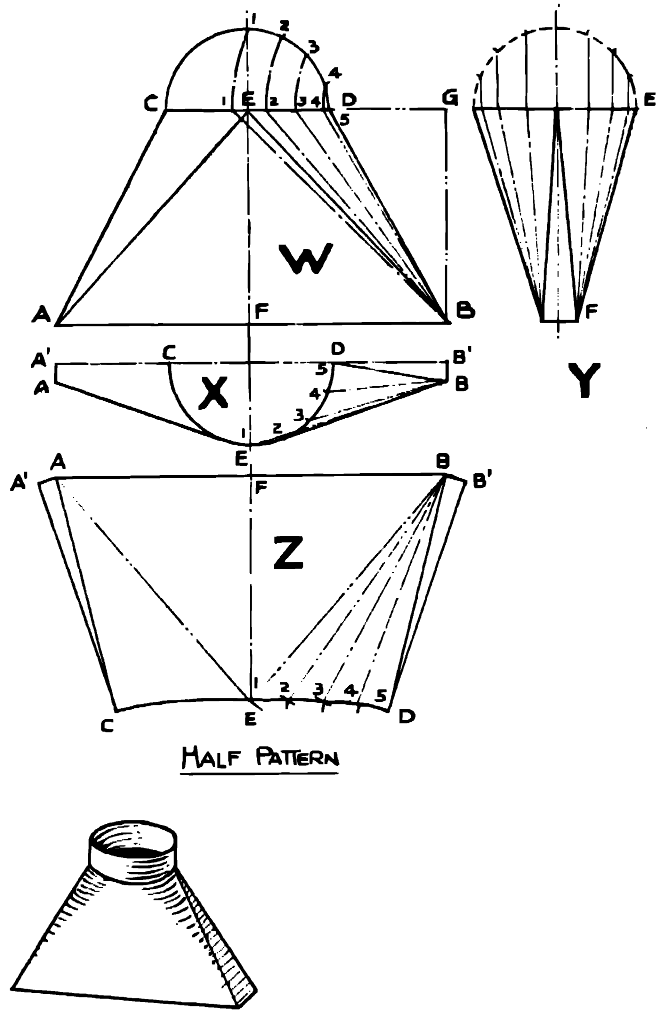


Fig. 282.—Fish-tail spout (in two pieces).

Fishtail Spout (in one piece) (Fig. 283).—Draw the elevation ABCDB (Fig. W) and add a half plan (Fig. X) on the base, also the end elevation (Fig. Y.)

Describe a semicircle on CD with centre E and divide one-half of this into four equal parts. Extend DB and draw a line through E and G (the centres of radii) to intersect this in J.

Normal to AB, project J perpendicularly, with a line to cut extensions of AB and CD in L and K. Now with K as centre and KL, KM, KN, and KP radii describe arcs to cut CD in P^1, N^1, M^1, and L^1.

Similarly, with L as centre and LQ, LR, LS, and LT radii describe arcs to cut AB in Q^1, R^1, S^1, and T^1. Add radial lines Q^1L^1, R^1M^1, S^1N^1, and T^1P^1.

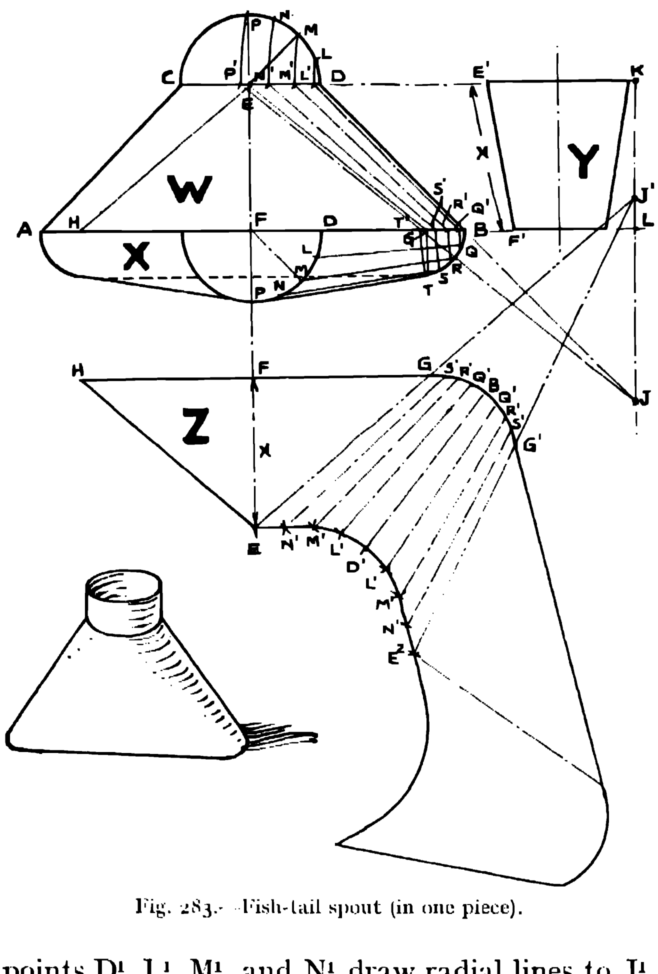


Fig. 283.—Fish-tail spout (in one piece).

The development of the pattern Fig. Z is obtained as follows: commence by extending the centre line EF and normal to this draw HG. Now measure perpendicularly FE equal F^1E^1 (Fig. Y). Connect HE and EG, extending the latter line to cut KL in J^1. Now with J^1 as centre and radii JD, JL^1, JM^1, and JN^1 (Fig. W) describe arcs near D^1, L^1, M^1, and N^1. Next set compasses to LD (Fig. W) and with this as radius and E as centre (Fig. Z) describe a short arc to cut arc already drawn at N^1 in N^1. Again with the same radius and N^1 as centre, cut arc at M^1 in M^1. Repeat to obtain the correct position of L^1 and D^1. Draw a curve through points thus obtained. Through points D^1, L^1, M^1, and N^1 draw radial lines to J^1 and set off on these lines distances DB, Q^1L^1, R^1M^1, and S^1N^1, obtained from Fig. W and draw a curve through these points. Complete the curve EE^2 and join E^2J^1 to form one-half of the pattern.

Unequal Tapering Spout with Round Ends (in two pieces) (Fig. 284).—Fig. W shows the elevation of the spout with base AB and top CD. A half plan is drawn at Fig. X and an end elevation at Fig. Y. Project the centres of end arcs E^1 and F^1 perpendicularly to cut AB in E and CD in F. Extend DB and produce FE to intersect same in G. Project this perpendicularly to CD, cutting same in H.

With F as centre describe a quarter circle of FD radius and divide this into four equal parts. Now with H as centre describe arcs through points thus obtained to cut CD in points 1, 2, 3, and 4. Add radial lines G1, G2, G3, and G4. Commence drawing the development (Fig. Z) with a perpendicular line JK equal J^1K^1 (Fig. Y). Next set off horizontally distances JF and KE (see Fig. W). Join FE and extend same a distance EG (see Fig. W). With G as centre and radii G1, G2, G3, G4, and G5 describe arcs near points 2, 3, 4, and 5. Now set compasses to a radius equal one division on quarter circle on FD (Fig. W) and with F (Fig. Z) as centre, cut previously drawn arc at 2 to obtain point 2. Repeat, using the same radius to obtain true position of points 3, 4, and 5 and join DG, also draw a curve through points 1 to 5. The curve EB is obtained using G as centre and radii G6, G7, and G8 (see Fig. W) to cut G2, G3, and G4 in 6, 7, and 8, then draw a curve through these points and duplicate the half pattern thus obtained.

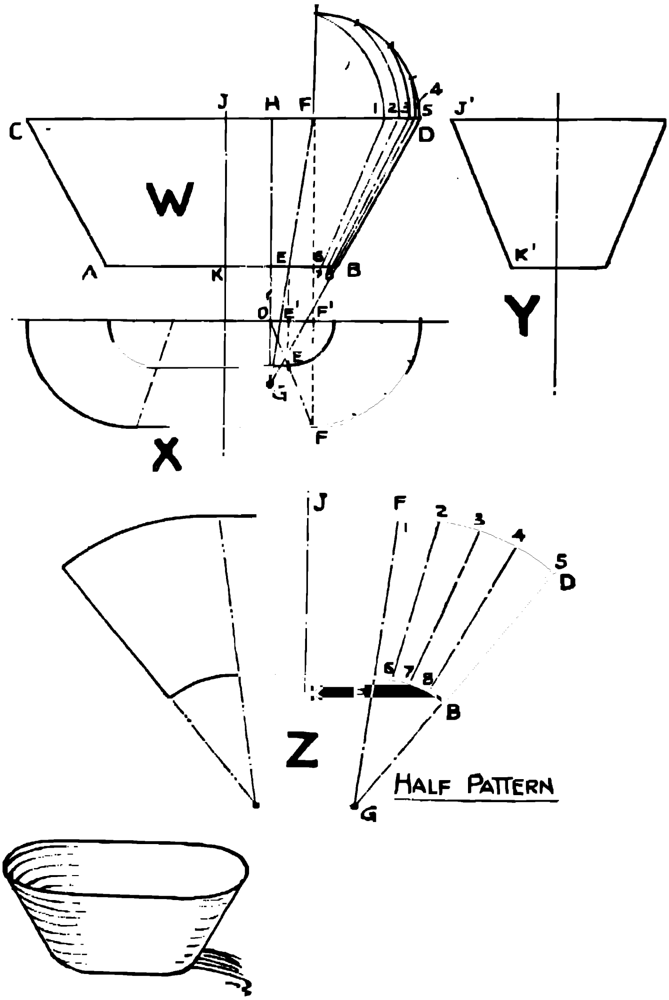


Fig. 284.—Unequal tapering spout with round ends (in two pieces).

Tapered Spout (in one piece) (Fig. 285).—This type of spout cannot be treated as a cone and must be developed by triangulation.

Draw the elevation AE51 (Fig. V) and add the half plan (Fig. W). Divide the semicircle AE into four equal parts and project perpendicularly to cut AE in BC and D. Describe a semicircle on the top of the spout, and divide this also into four parts, projecting points perpendicularly to the top. Join B2, C3, and D4. Now project points 1, 2, 3, 4, and 5 from Fig. V

to the half plan to the semi-ellipse there. Join D4, C3, and B2, also D5, C4, B3, and A2.

To develop the pattern for the spout it is necessary to obtain the true lengths of the latter lines by the aid of offset diagrams (Figs. X and Y).

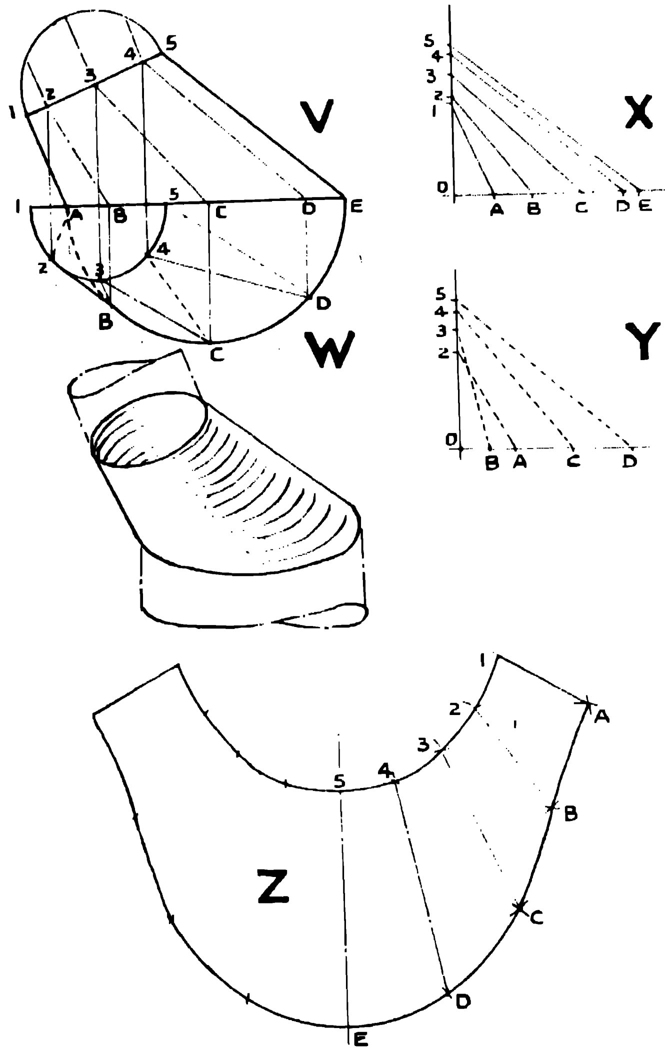


Fig. 285.—Tapered spout in one piece.

Extend the base line AE and draw a perpendicular line through this at O. Now project points 1, 2, 3, 4, and 5 horizontally from Fig. V to cut the perpendicular line in similar points. Set off horizontally distances A1, B2, C3, D4, and E5 obtained from Fig. W. Join A1, B2, C3, etc., on the diagram. The lengths of these lines measured here are now true lengths. Fig. Y shows the offset diagram for the diagonal lines D5, C4, B3, and A2. This is drawn making the perpendicular height of points 2, 3, 4, and 5 as previously, and horizontal distances OA, OB, OC, and OD equal A2, B3, C4, and D5.

To draw the pattern (Fig. Z): commence with a perpendicular line E5 (length from Fig. V). Now set compasses to D5 (Fig. Y) and with point 5 as centre describe an arc near D. With E as centre and ED (Fig. W) radius cut arc at D. Set compasses to one-quarter of the circumference of the semicircle on top of the spout and with point 5 (Fig. Z) as centre describe an arc at point 4 to be cut by an arc of D4 radius (see Fig X) in point 4. This establishes the position of points D and 4. Points C and 3, B and 2, etc., are obtained by the same method,

using radii from Figs. X and Y. Distances 5–4, 4–3, 3–2, 2–1 are equal and the same applies to distances ED, DC, CB, and BA.

When all points are obtained, curves are drawn from 1 to 5 and EA, A1 being connected by a straight line to complete the half pattern which is duplicated to the left of the centre line E5.

Square to Round Pipe Cut Obliquely (Fig. 286).—This is an example which could be developed taking the corners as portions of oblique cones, but to avoid unnecessary complication of lines it is preferred to obtain the pattern by use of the triangulation method.

Draw the elevation Fig. V and plan Fig. W. Add a semicircle on the top (Fig. V) dividing this equally and dropping perpendiculars as illustrated. Also draw radial lines C1 to C9 and B1 to B5. Divide the semicircle in plan into eight equal parts as shown and again connect the numbered points to B and C as shown.

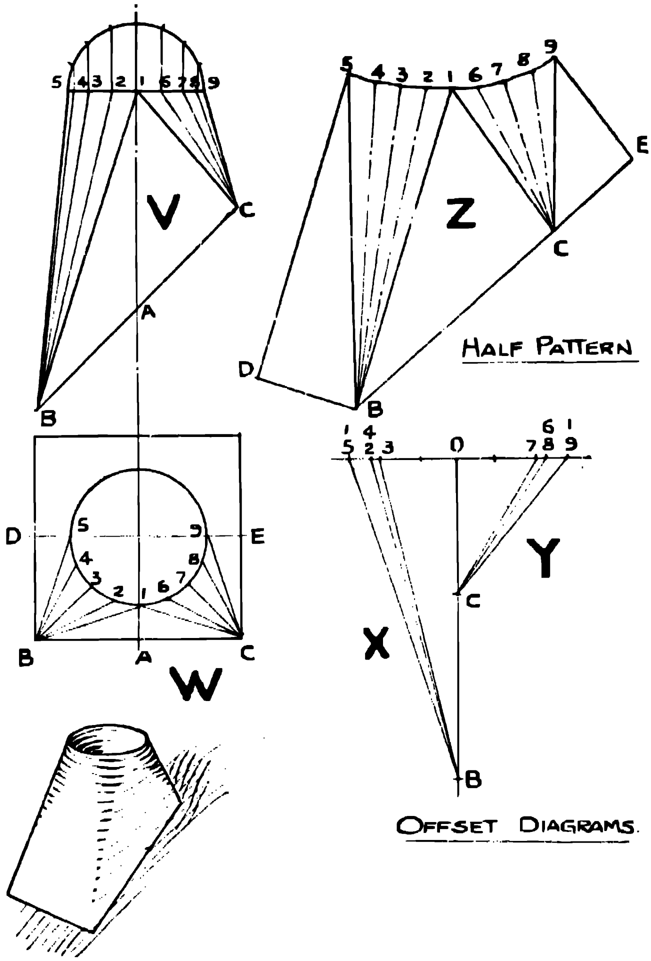


Fig. 286.—Square to round pipe cut obliquely at base.

Offset diagrams (Figs. X and Y) are next drawn to obtain the true lengths of C1 to C9 and B1 to B5. Draw a perpendicular line OB, making OB equal the perpendicular height from B to the top of the pipe. Also mark OC equal the perpendicular height from C to top of pipe (Fig. V). Now measure distances C1 to C9 (Fig. W) and with O as centre set these off to the right on a horizontal line. Similarly, measure distances B1 to B5 and set these off to the left of O. Connect B to points 1, 2, 3, 4, and 5, and C to points 1, 6, 7, 8, and 9. Now proceed to draw the half pattern (Fig. Z) commencing with a line BC parallel with and of same length as

BC (Fig. V). Now with B as centre and radius B1 (see Fig. X) describe an arc at 1 to be cut by an arc of C1 radius struck from C as centre.

Now with radii B2, B3, B4, and B5 (Fig. X) draw arcs at 2, 3, 4, and 5, also with radii C7, C8, and C9 describe arcs at 7, 8, and 9. Next set compasses to radius equal to one space in the semicircle (Fig. W) and commencing from point 1 as centre describe arcs on either side to cut previously drawn arcs at 2, 3, 4, and 5, also 6, 7, 8, and 9.

Draw curves through latter points and connect numbered points to B and C as illustrated. Now set compasses to CE (Fig. W) and with C as centre (Fig. Z) describe an arc near E to be cut by an arc of C9 radius (see Fig. V) in E. With centre B describe an arc of BD radius to be cut by an arc of D5 radius struck from point 5. Connect points 5, D, B, C, E, and 9 to complete the half pattern.

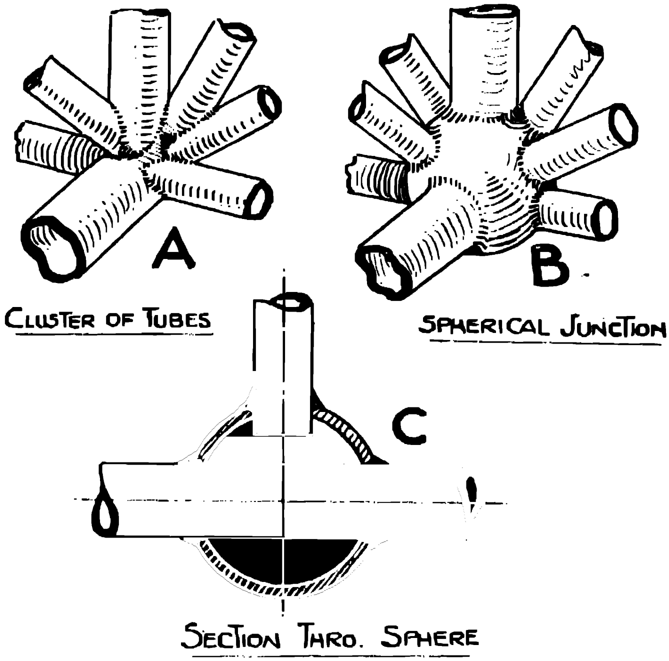


Fig. 287.—Method of joining a cluster of tubes.

Method of Joining a Cluster of Tubes (Fig. 287).—Where a number of comparatively small tubes are to be connected by welding in a cluster as shown it is difficult to form the ends correctly at the junction. It is, also, almost impossible to make a neat or efficient job of the welding if done in the manner shown.

Fig. B illustrates a solution to the problem, and it will be seen to consist in the use of a hollow sphere at the junction. By this means the holes may be accurately jig-drilled in the spheres and the tubes when in position are held correctly while an efficient weld can be made all round the base of each tube. Another advantage of the use of this system is that the ends of tubes do not require to be shaped or fitted at the junctions.

Fig. C shows a section through the joint. The spheres are made in halves and welded together and can be produced fairly economically by the use of simply made punches and dies.

The idea has been developed in the U.S.A., where it has been applied in the construction of tubular hand-rails, but this does not exhaust its

possibilities, as the system could be applied for piping liquids or gases or used in the construction of light girders, towers, etc.

Spiral Conveyor Worming and Chutes (Fig. 288).—Figs. V and W illustrate examples of ribbon-type conveyor worms which operate on the principle of an Archimedean screw being revolved in a U-shaped trough to convey grain, sand, and semi-liquids. The type shown at Fig. W is tapered at one end to concentrate the pressure here.

Figs. X, Y, and Z show spiral types of gravity chutes used for the conveyance of various kinds of goods from upper to lower floors. The chute consists of a tubular pillar to which is fixed a sectional ribbon-type worm having a raised rim at the outer circumference.

This type of chute occupies little floor space, needs no motive power, and can be arranged for loading or discharge at any point in its length. The type shown at Fig. X is a single-threaded chute, having a single path for the conveyance of goods.

Fig. Y shows a double-threaded chute, allowing one spiral to discharge at any intermediate point while the other carries goods past that flat without interruption. The type of chute shown at Fig. Z is a hollow chute suitable for bags, bales, or soft goods.

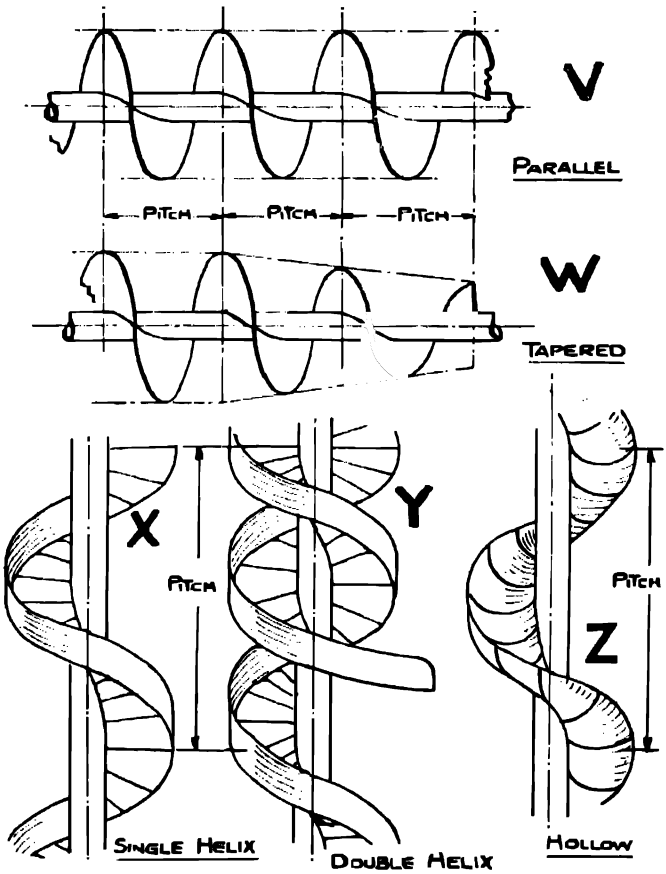


Fig. 288.—Spiral conveyor worming and chutes.

Development of Ribbon-type Conveyor Worm (Fig. 289).—Fig. V illustrates a parallel worm and the dimensions necessary for its development. The spiral ribbon can be formed in certain cases by winding flat strip steel on edge similar to a spring, but usually, owing to its comparatively great depth, it is made in segments one pitch in length, being riveted

together and fixed to the central shaft or tube by bolting, riveting, or welding.

To develop the worm sections it is necessary to obtain the spiral circumferences D and E (Fig. V) and Fig. W shows how they can be obtained diagrammatically. To draw the diagram, commence with a perpendicular line HG equal to the pitch of the worm and at right angles to this FG equal the maximum circumference of the worm. Also set off on FG a distance JG equal the minimum circumference of the worm. Join HF and HJ. FH represents the maximum spiral circumference D and HJ the minimum spiral circumference E.

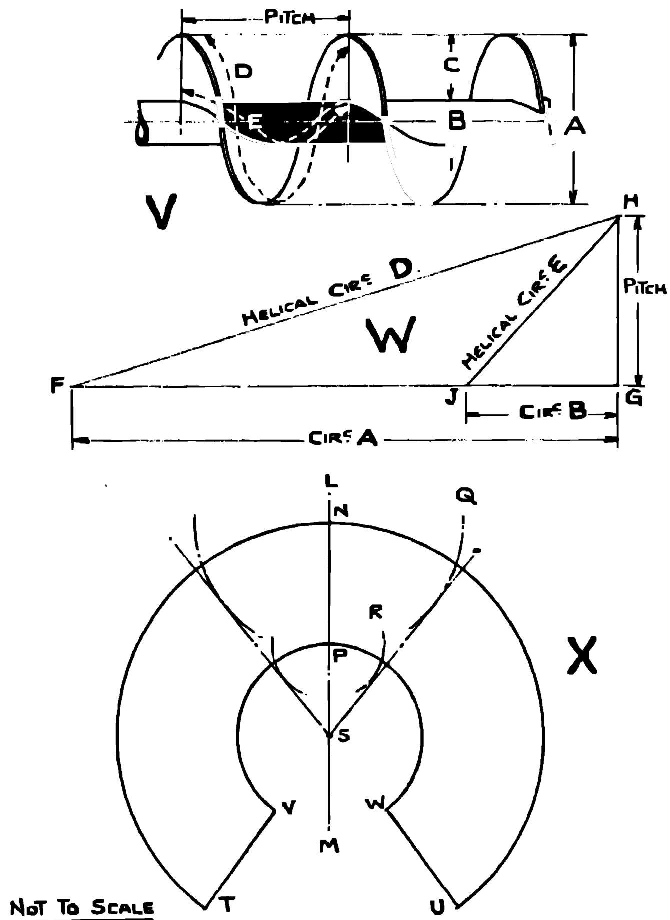


Fig. 289.—Development of ribbon-type conveyor worm.

To develop the pattern for one section or pitch of the worm, draw a perpendicular line LM (Fig. X) and on this set off a distance NP equal C (Fig. V). Now measure HF and HJ (Fig. W) and divide each of these by, say, 10. Set compasses to $\frac{HF}{10}$ and with N as centre describe arc Q. Re-set compasses to $\frac{HJ}{10}$ and with P as centre describe arc R. Next draw a line tangential to arcs Q and R to intersect centre line LM in S. Now set compasses on S and with SP and SN radii describe arcs VW and TU respectively. The lengths of the latter arcs are equal to the minimum and maximum spiral circumferences E and D.

Join TU and UW to complete the development of one pitch or flight of the worm.

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Tapered Ribbon-type Conveyor Worm (Fig. 290).—This is developed exactly as in the case of the parallel worming at the commencement. The pattern EFHG is next altered to show the taper. Set off on GH a distance GJ equal C^1. Divide JH into eight equal parts, also divide the circumference FH into a similar number of parts and draw radial lines through J, K, L, M, N, P, and Q to R. Now with centre R and radii R1, R2, R3, etc., to R7 cut the foregoing radial lines in points 1 to 7 respectively. Draw a curve FJ through these points.

The area FJGEF is the pattern for the tapered portion of the worm. Additional flights may be drawn off by continuing the spiral curve by the method given.

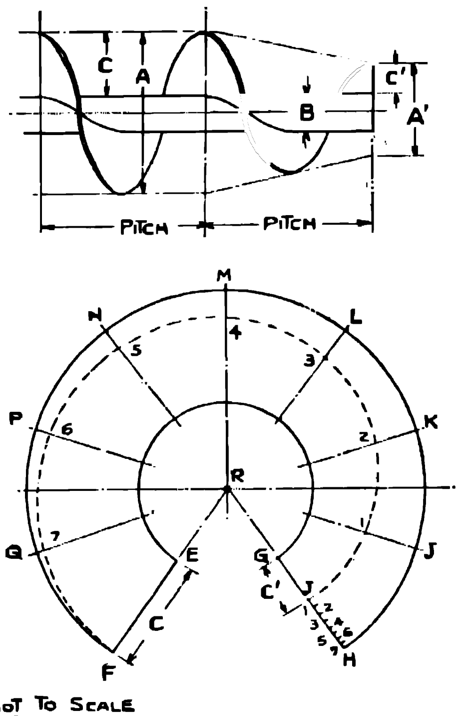

Fig. 290.—Tapered ribbon-type conveyor worm.

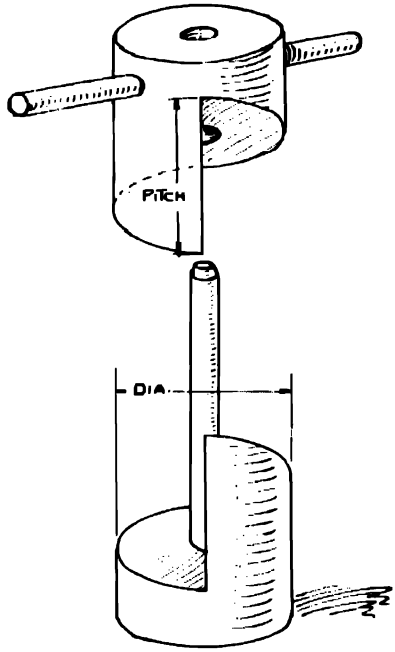

Fig. 291.—Dies for forming ribbon worming.

Dies for Forming Ribbon Worming (Fig. 291).—To form the spiral on conveyor-worm sections they are heated and formed in hand-operated dies, as seen in the illustration. As will be seen, the dies consist of top and bottom blocks of cast iron shaped to the correct spiral. The bottom half has a spindle fitted at the centre, and top block, which is provided with handles, slides easily on this.

To form the worm sections they are individually heated and, being threaded over the spindle, the top block is brought down with considerable force, thus forming the plate to the correct spiral.

Spiral Gravity Chute with Flat Bottom (Fig. 292).—The bottom plates of gravity-type spiral chutes are developed exactly as ribbon-type worming, but with this difference that they are formed up from segments which are overlapped and riveted together.

To develop the segments obtain the maximum and minimum spiral circumferences by drawing the diagram Fig. W to a suitable scale. Make DG equal the pitch of the spiral, FG the maximum circumference, and JG the minimum circumference. FD and JD now represent the maximum and minimum spiral circumferences.

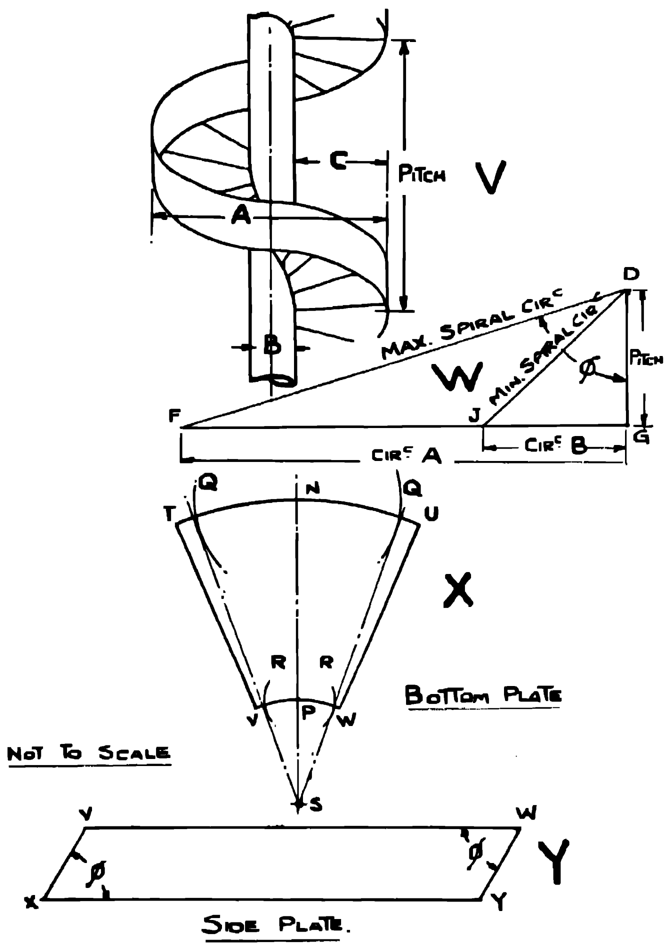

Fig. 292.—Spiral gravity chute with flat bottom.

To develop the pattern for a segment, draw a perpendicular line (Fig. X), and set off on this NP equal C (Fig. V).

Now divide FD by, say, 10, and with this as radius and N as centre describe arcs at Q. Similarly with P as centre and $\frac{JD}{10}$ radius describe arcs R. Tangential to arcs Q and R draw lines to intersect at S. Now with S as centre and radii SN and SP, describe arcs QQ and RR. Extend the latter arcs to form the necessary overlap allowances QT and QU, drawing radial lines through T and U to S. To develop the pattern (Fig. Y) for the rim plates draw off the plates to the parallel depth required and cut the ends XV and YW to the angle ϕ obtained from Fig. W. In the construction of these chutes it is usual to rivet the sections together and support same by means of palmed bolts to the centre tube. The rim plates are secured to the sections by angle bar by riveting and they are stiffened at the top edge by use of flat bar strip. All the bottom and rim

plates must be flush riveted and arranged to overlap correctly to reduce friction to a minimum.

Hollow Type of Spiral Chute (Fig. 293).—Fig. V illustrates a hollow type of gravity spiral chute and Fig. W shows the plan view of same.

Draw a semicircle HM at Fig. W, dividing this into four equal parts and projecting the points thus obtained horizontally to obtain points J, K, and L. With centre T describe circles of TL, TK, and TJ radii.

Now draw the pitch diagram Fig. X making CB the pitch of the spiral. The maximum circumference of the spiral AB is next set off horizontally, also DB the minimum circumference. Now divide AD into four equal parts AE, EF, FG, and GD. Add radial lines through points A, E, F, G, and D to C.

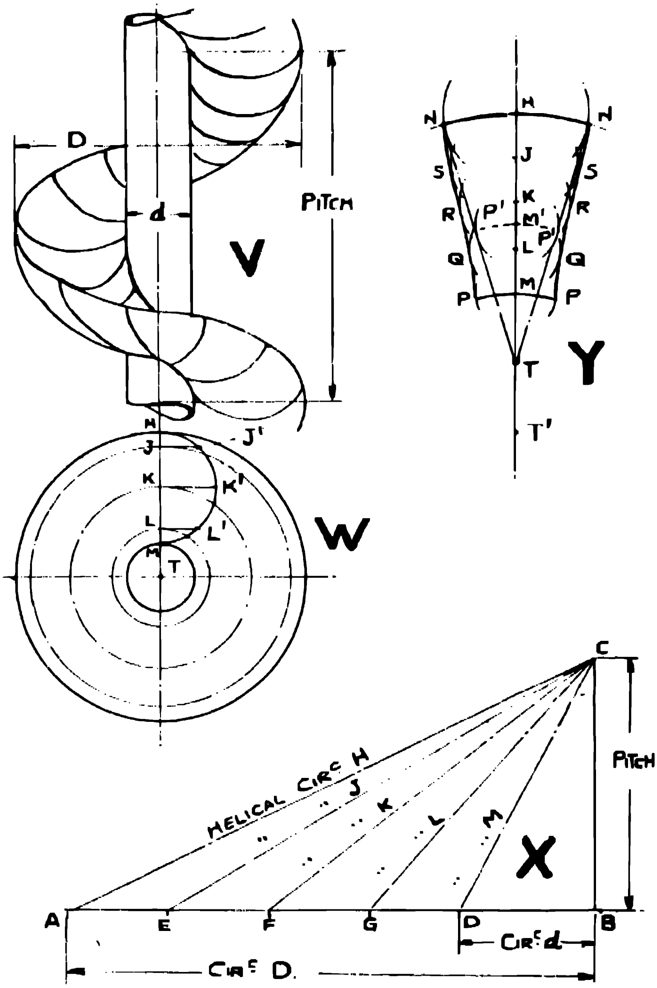

Fig. 293.—Hollow type of spiral chute.

To develop a section of the chute, commence by drawing a perpendicular centre line (Fig. Y) and select a point H. Set off HM^1 equal HM (Fig. W). Now divide AC (Fig. X) into, say, 20 (if the number of sections to form one pitch is 10). Set compasses to this and with H as centre describe arcs at N. Next set compasses to DC divided by 20, and with M^1 as centre describe arcs P^1. Draw lines tangential to arcs N and P^1 to intersect at T. With this as centre and TH as radius describe arc NN, also with TM^1 radius describe arc P^1P^1.

Now set off HJ^1. J^1K^1, K^1L^1, and L^1M (obtaining distances from Fig. W). Set compasses to TM^1 and with T^1 as centre describe arc PP, making this equal P^1P^1 in length.

Now with $\frac{EC}{20}$ as radius (Fig. X) and J^1 as centre describe arcs at S. Next divide FC by 20 and with this as radius and K^1 as centre describe arcs at R. Finally with $\frac{GC}{20}$ radius and centre L draw arcs Q. Tangential to all arcs draw curves NP to complete the pattern for the section. Allowance must be made on NP for overlap and when forming up the sections a semicircular templet should fit at the ends.

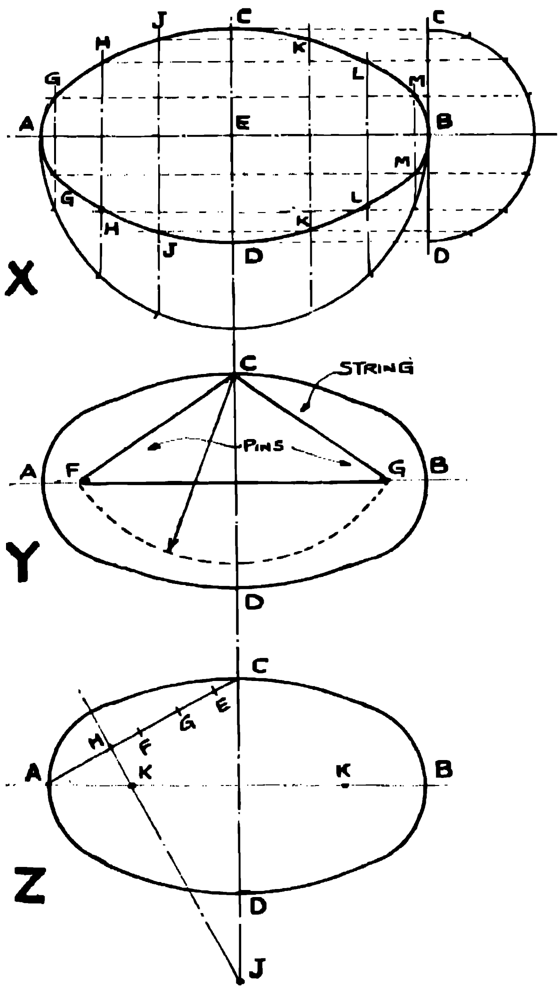

Fig. 294.—Methods of drawing ellipse.

Methods of Drawing an Ellipse (Fig. 294).—Fig. X shows how the ellipse may be drawn by the aid of semicircles. Draw the horizontal centre line, making AB equal the major axis of the ellipse and perpendicular to this add the minor axis CD intersecting AB in E. With E as centre and EA radius draw a semicircle AB. Erect a perpendicular line at B and describe here a semicircle of EC radius.

Divide both semicircles into eight equal parts. Project horizontal and vertical lines through the points of division of semicircles AB and CD respectively to intersect in points G, H, J, K, L, and M, and draw a curve through these points.

At Fig. Y is shown a popular method in which a loop of cord is used in conjunction with two pins or nails. Draw centre lines to intersect at E and mark the major and minor axis widths equally on either side, making AB the major axis and CD the minor axis.

With C as centre and radius equal half the major axis length describe an arc to cut AB in F and G. Nails are fixed at the latter points and a loop of cord CGFC made to pass round these as shown. If the point of the pencil be placed inside the loop as at C and swung round, keeping the loop taut, an ellipse may be drawn.

Another method of describing an ellipse is illustrated at Fig. Z, where use is made of two radii.

Draw the horizontal and perpendicular centre lines and mark off major and minor axes AB and CD. Next indicate the diagonal line AC and on this set off AE equal half the major axis and AF equal half the minor axis. Bisect FE in G, then bisect AG in H. Normal to AC and through H draw a line to intersect the perpendicular centre line J and the horizontal centre line in K.

Now set compasses to KA as radius and with K as centre describe arcs at the small ends of the ellipse. Also with J as centre and JC radius describe an arc to join the previously drawn arcs. Repeat this arc, drawing same through D.

Car Bonnet (Top Part) Formed in Two Pieces (Fig. 265).—This is developed as though it were a quarter of an elliptical cone frustum, although in some cases the top curve may be replaced by a straight line. The method of development used is that of triangulation.

The elevation (Fig. A) shows the bonnet in a side view. Fig. B illustrates the end elevation. Draw the outline of these views and divide BK up as required. Also divide AJ and connect CD, EF, and GH as shown. Add dotted diagonal lines BC, DE, FG, and HJ, all as shown at Fig. B.

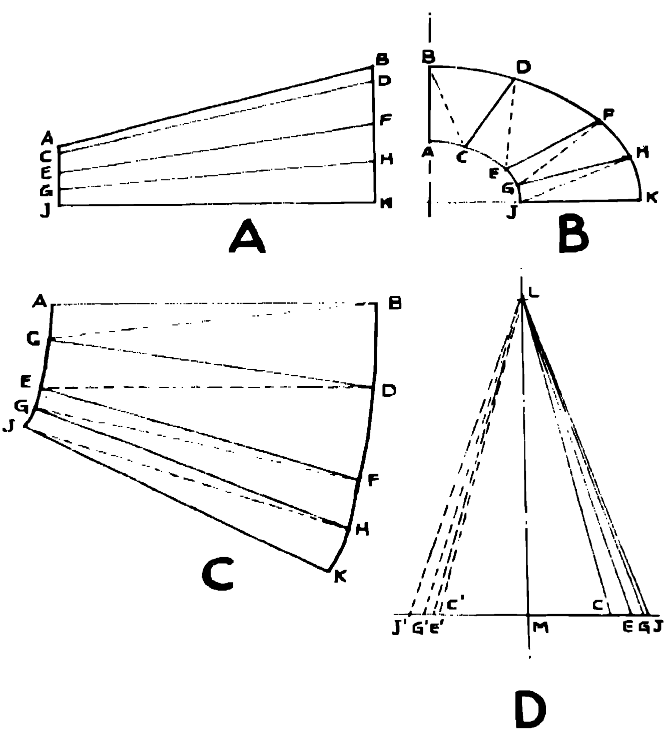

Fig. 295.—Car bonnet (top portion).

Next, project points D, F, and H to cut BK at Fig. A, also project C, E, and G to cut AJ as shown.

An offset diagram (Fig. D) is next drawn, commencing with a perpendicular line of length LM equal JK (Fig. A). Draw a horizontal line through M, and to the right of M set off MC equal CD, ME equal EF, MG equal HG, and MJ equal JK, all as measured at Fig. B. Now to the left of M set off MC equal BC, ME equal DE, MG equal FG, and MJ equal HJ, as measured at Fig. B.

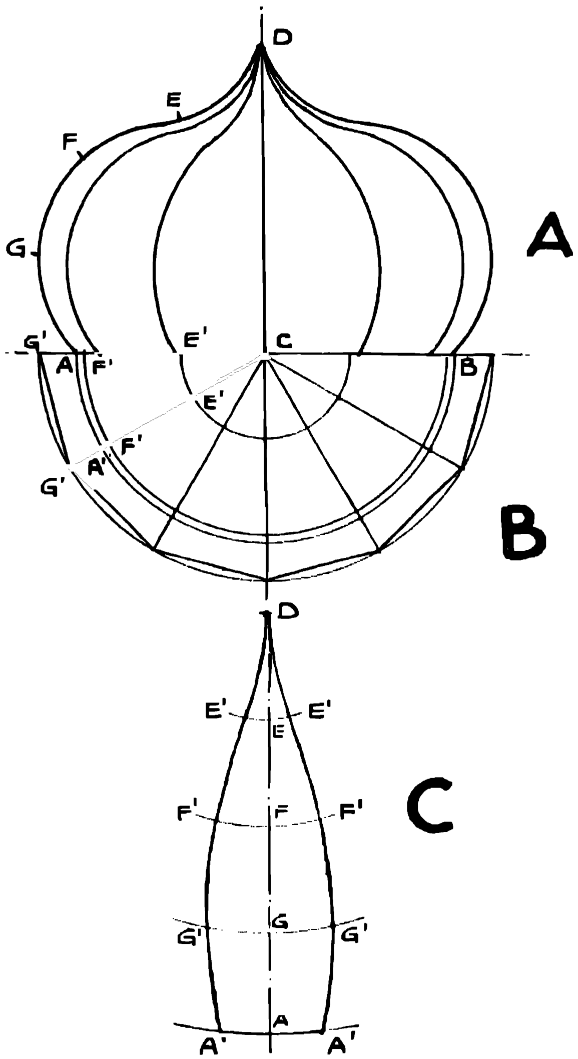

Fig. 296.—Dome covered in twelve sections.

Join all points J, G, E, and C to L. The lengths LC, LE, LG, and LJ on the right-hand side of diagram are the true lengths of lines DC, FE, HG, and KJ, and lengths measured on the left-hand diagram are true lengths of diagonal lines shown dotted at Fig. B.

Next proceed to draw the development as seen at Fig. C. Commence by drawing a horizontal line of length AB. Set compasses to distance AC (Fig. B) and with A as centre (Fig. C) describe an arc at C. Re-set compasses to LC^{1} radius (Fig. D) and with B as centre cut arc at C in point C. Set compasses to BD (Fig. B) and with B as centre (Fig. C) describe an arc at D to be cut in point D by an arc of LC radius struck from C as centre. This completes the first portion of the development, the other three sections are obtained by a repetition of the method just described, using the requisite radii as indicated at Fig. C. Connect AJ and BK with curves and join JK to complete the development of the pattern for the top half of bonnet.

Dome Covered in Twelve Sections (Fig. 296).—Draw the elevation

(Fig. A) and add a half plan (Fig. B), dividing this into six equal parts as shown. Now divide the curved line AD into equal parts, and drop points E, F, and G to the base to obtain points E^1, F^1, and G^1. With C as centre and radii CE^1, CF^1, CA, and CG^1 describe semicircles at Fig. B. Next draw a perpendicular line at Fig. C and mark a point D. Set compasses to DE (Fig. A) and with D as centre (Fig. C) describe an arc E^1E^1,

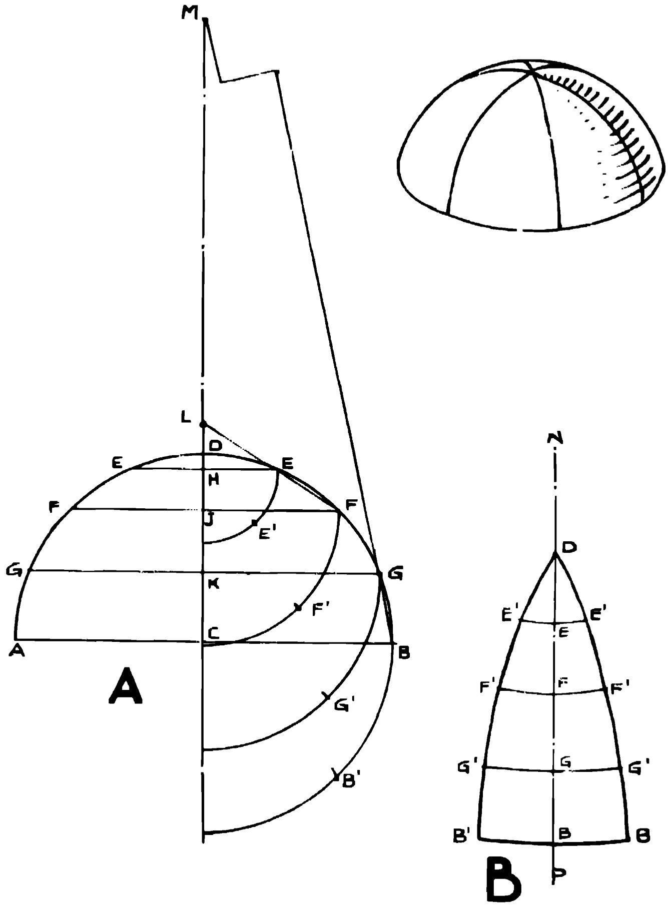

Fig. 297.—Conical method of development of sphere.

making the length of this equal E^1E^1 (Fig. B). Now with radii DF, DG, and DA (as measured at Fig. A) describe arcs F^1F^1, G^1G^1, and AA^1, making lengths of these arcs equal similar arcs at Fig. B. Join DA^1 with curved lines as shown to complete the pattern for one section of the dome covering. The pattern thus obtained is suitable for hollowing. If the sections are to remain flat, the lengths of arcs E^1E^1, F^1F^1, etc., in the development should be shortened to suit the chordal lengths E^1E^1, F^1F^1, etc., as measured at Fig. B.

Conical Method of Development of Sphere (Fig. 297).—Fig. A shows a semi-sphere which is to be developed for construction in eight pieces, each piece to be hollowed. The method of development assumes that the sphere is cut in horizontal sections, and that each section represents the frustum of a cone, thus simplifying the development.

Draw the semicircle as seen at Fig. A, making the diameter AB. Divide DB into equal parts and draw lines GG, FF, and EE. If lines be drawn to join BG and AC, it will readily be seen that the portion of the

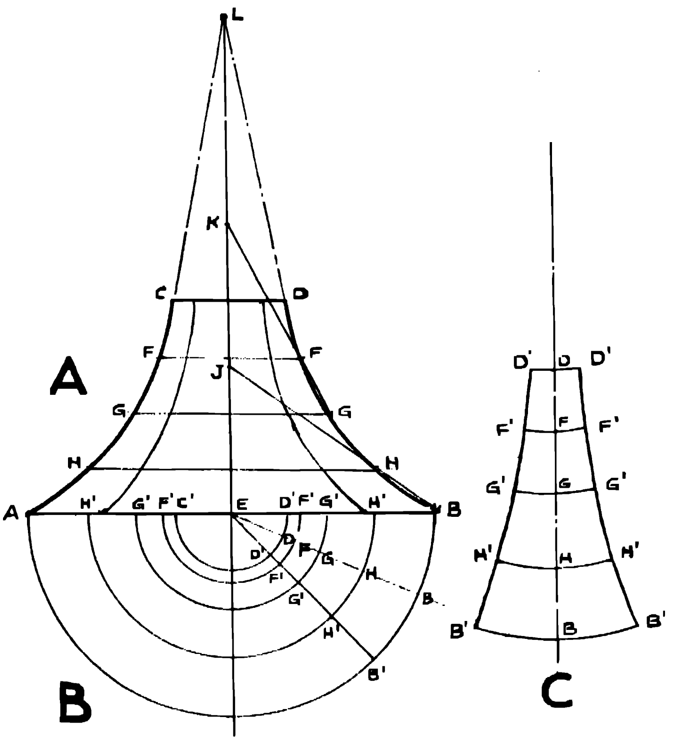

Fig. 298.—Conical method of development of bell mouth.

sphere ABGGA represents the frustum of a cone with base AB. The same applies to the portion FFEEF.

Draw lines through GB and EF and extend same to cut the perpendicular centre line at M and L. With radii HE, JF, KG, and CB describe quarter circles as shown and bisect these at E^1, F^1, G^1, and B^1.

To develop the pattern for one portion draw a perpendicular line NP at Fig. B and mark a point D on this. Set off DE, EF, FG, and GB (see Fig. A), and with LE radius (Fig. A) describe the arc E^1E^1 at Fig. B, making the length of this equal EE^1 (Fig. A). Add arcs F^1F^1, G^1G^1, and B^1B^1, taking as radii LF, MG, and MB (Fig. A) respectively. Curves DB^1 complete the development of the pattern (Fig. B).

Conical Method of Development of Bellmouth (in eight parts) (Fig. 298).—Fig. A illustrates the elevation of the object. Draw this and divide DB into four equal parts. Through points thus found draw horizontal lines FF, GG, and HH. Draw lines through HB, FG, and DF, extending same to cut the centre line in J, K, and L respectively. Drop points D, F, G, and H to the base line, and with E as centre and radii ED^1, EF^1, EG^1, EH^1, and EB describe semicircles in the half plan (Fig. B). Bisect the quarter circle to the right of centre line in B^1.

To develop one section for hollowing. At Fig. C draw a perpendicular centre line and mark on this a point D. Set off on this distances DF, FG, GH, and HB as measured at Fig. A.

Now set compasses to LD (Fig. A) and describe an arc through point D (Fig. C). Reset to KF, KG, JH, and JB in succession, and describe arcs through F, G, H, and B (Fig. C).

Make lengths of arcs D^1D^1, F^1F^1, G^1G^1, etc., all as measured at Fig. B, and add curves D^1B^1 to complete the pattern.

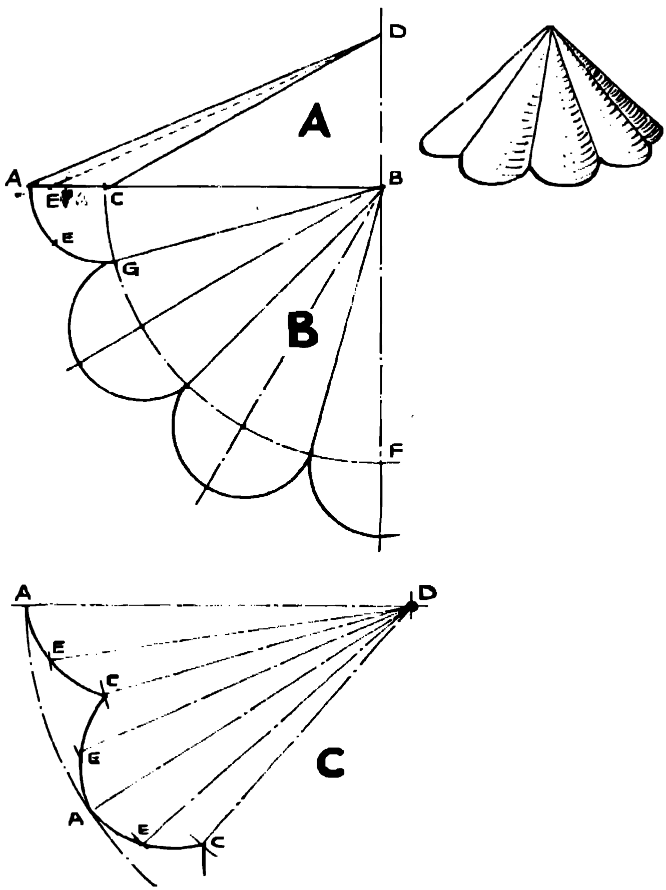

Fig. 299.—Ornamental conical object.

Ornamental Conical Object (Fig. 299).—This object is composed of a series of partial oblique cones and is developed along the same lines. To develop the object commence by drawing the half elevation seen at Fig. A, making CB equal half the minimum diameter, and BD the perpendicular height. Before drawing AD proceed to draw the plan (Fig. B).

With centre B and radius BC describe a quarter circle CF. Divide this into six and draw radial lines to B through points found. With centre C and radius CG describe quarter and semicircles as shown. Now add line

AD in the elevation. Bisect arc AG in E and with centre B and radius BE cut the base line AB in E^1.

To draw the partial pattern. Commence with a horizontal line at Fig. C, marking off AD equal to AD (Fig. A).

With radii DE^1 and DC (Fig. A) describe arcs at E and C at Fig. C. Set compasses to AE (Fig. A), and with A as centre (Fig. C) describe an arc to cut existing arc at E to obtain point E. Keeping compasses set, describe an arc to cut arc at C in point C from E as centre. Draw a curve AC to complete one-half pattern for one section of the object. For greater accuracy the arc AG (Fig. B) should be divided into as many parts as possible.

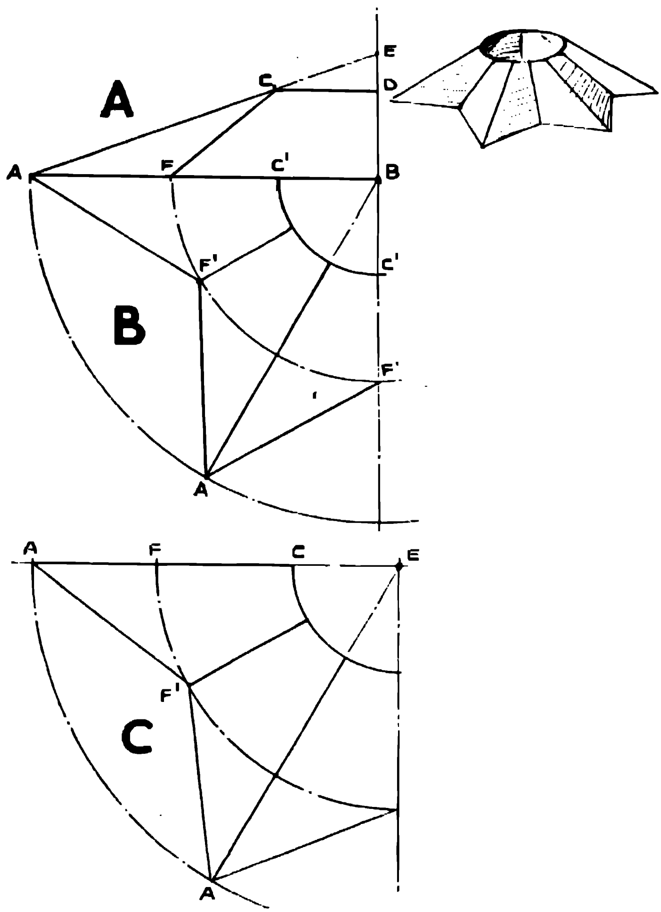

Fig. 300.—Ornamental star-shaped base.

Object with Star-shaped Base and Circular Top (Fig. 300).—Commence by drawing the quarter plan (Fig. B), showing the points of star with a quarter circle of BA radius, also add quarter circles FF and C^1C^1.

Now draw the half elevation (Fig. A), with BD the perpendicular height of the object.

Draw the diagonal line AC and produce this to cut the centre line at E. Add the line FC. To draw the partial pattern commence with horizontal and perpendicular centre lines (Fig. C) to intersect at E. Measure EA at Fig. A and set this off at Fig. C. Also set off EC and CF as measured at Fig. A and with centre C describe arcs through these points. Set compasses to AF^1 (Fig. A) and cut the quarter at F^1 (Fig. C). A radial line is next drawn through F^1 to complete one-half of the pattern for one point of the star and this can be repeated as required.

Ornamental Star-shaped Base (Fig. 301).—This object is similar to the foregoing example with additional partial oblique cones between the points of the star.

Draw Fig. B showing a quarter plan of the object with the star points divided off equally. Next draw the elevation (Fig. A), making BD the height of the object and CD the radius of the circular top. Add a line AC and produce this to cut the centre line at E.

With centre B and radii BG and BH cut the base line AB at H^1 and F^1. Next, with radius F^1H^1, describe an arc H^1F. Divide this into equal parts as shown, and with centre B and BJ radius cut the base line AB at J^1.

The pattern is drawn commencing with a horizontal centre line. Mark a point E on this and set off EA as measured at Fig. A. Also set off EC and CF^1 and with E as centre describe arcs CC^2 and F^1K. Next set compasses to AK (Fig. B) and with A as centre (Fig. C) intersect arc at K in point K.

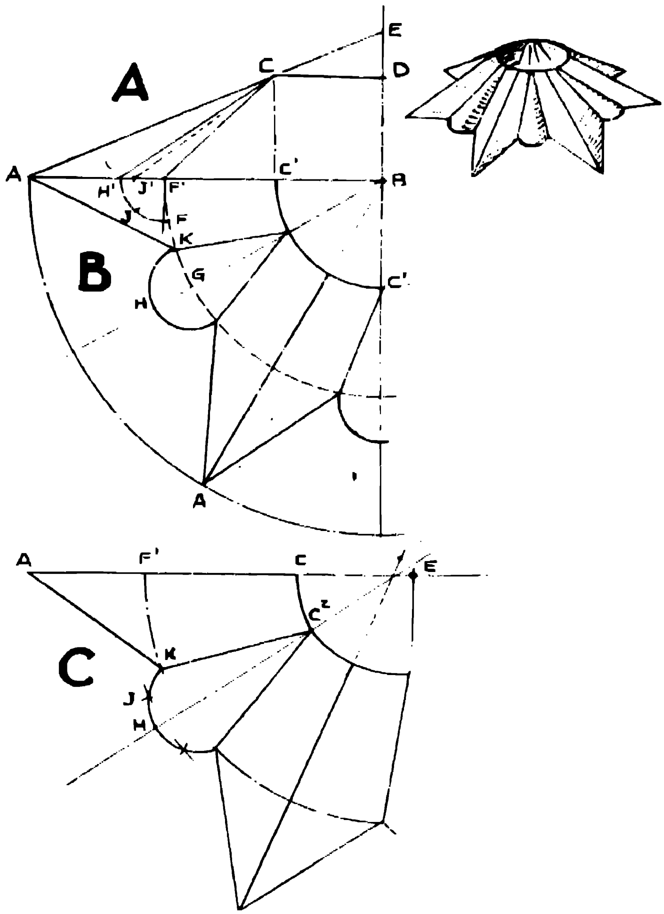

Fig. 301.—Ornamental star-shaped base.

Now set compasses to CH^1 and CJ^1 (Fig. A) and with C^2 as centre (Fig. C) describe arcs approximately at J and H. Re-set compasses to H^1J and with K as centre describe an arc to cut existing arc at J. Repeat with J as centre to cut arc at H, and draw the curve KH to complete one-half pattern for a starpoint and cone.